

# ASSESSING THE ENVIRONMENTAL IMPACT OF COAL ASH DISPOSAL

GAVIN M. MUDD, JAYANTHA KODIKARA

Dept. Civil & Building Eng., Victoria University of Technology (Footscray Campus)

TERRY McKINLEY

Geo-Eng Australia Pty Ltd (Notting Hill Office)

## 1. INTRODUCTION

Ash produced from the combustion of brown coal in Victoria's Latrobe Valley is currently slurried into ash disposal ponds for storage. Subsequent to a review of ash production rates at the Loy Yang Power Station, a number of options for ash pond management were considered. These included excavating aged ash from the existing pond and then depositing them downstream of the pond or into a nearby overburden dump.

Coal ash has previously been classified as prescribed waste by the Environment Protection Authority of Victoria (EPA). In 1994, following a submission to the EPA by the Environmental Affairs Unit of Generation Victoria, the EPA advised that they would classify the ash as low level contaminated soil. Any disposal of ash into the Loy Yang Overburden Dump would require lining and ongoing monitoring.

Prior to the reclassifying of ash, analytical testing was generally conducted on a total concentration basis and did not consider the leachable fraction of various elements from the ash. Thus, these previous work indicated high levels of heavy metals, with the EPA classifying the ash accordingly. It was hypothesised that after the ash has been disposed of in the pond for a period of 6 to 12 months, the process of field leaching would significantly reduce the soluble concentrations of various elements within the ash. Preliminary investigations by McKinley (1995) showed generally low levels of heavy metals that were within EPA criteria, although elevated concentrations of barium and mercury could be found near or slightly above the criteria. More extensive field investigations and laboratory tests were conducted to determine if the field leached ash, or *aged ash*, could be classified as fill material by the EPA for uncontrolled disposal. The costs of ash disposal could thereby be reduced by placing it in the overburden dump and demonstrating that the adverse impacts on the beneficial use of groundwater beneath the site were minimal.

## 2. METHODOLOGY

The current study of ash leaching involved the collection and testing ash in three states : namely, *aged ash*, which has been deposited in the pond about 6 to 12 months ago; *slurry ash* at the point of mixing within Loy Yang Power Station and at the corresponding discharge point to the ash pond; *fresh ash* from the electrostatic precipitators of Loy Yang A Power Station.

Samples of *aged ash* were collected during November 1995 from a total of 12 sites of the ash pond. The ash from these samples were subjected to an acid digestion analysis in which they

were immersed in a solution with a pH maintained at 5 for a period of approximately 18 hours. This test is a standard EPA method for classifying waste materials for disposal. The resulting leachates were analysed for major ions and selected heavy metals. The ash from three sites were also selected for further testing which included sequential batch leaching, and total decomposition analysis in order to facilitate the calculation of total leachable fractions of the major ash components and the selected heavy metals.

The sequential batch leaching procedure used for the *aged ash* was based on ASTM standards "D 4793 : Standard Test Method for Sequential Batch Extraction of Waste With Water" and "D 5284-93 : Standard Test Method for Sequential Batch Extraction of Waste with Acidic Extraction Fluid" (ASTM, 1994). The experiments were conducted using both neutral water and acidic water with an initial pH of 4 (the acidic buffer used was nitric acid). The value of the pH was chosen to represent the possible acidic leachate that has been observed to occur from inferior coal placed in the overburden dump where the ash would be dumped. A total of 100 g of each sample of aged ash was mixed with 2 litres of extraction fluid and shaken at room temperature for approximately 18 hours. The resulting leachate was then filtered from the ash residue and analysed for major ions and selected heavy metals. The ash residue was then mixed with another 2 litres of extraction fluid and shaken for a further 18 hours, with the leachate filtered and analysed for major ions and selected heavy metals.

Previous research at other Latrobe Valley power station complexes has shown that the hydraulic ash transport system can lead to the reduction of soluble fractions in the ash from the power station to the ash pond (Bone & Schaap, 1980). In order to investigate this issue, a series of ash slurry samples were taken from the hydraulic ash transport system over a 3 week period from February 29 to March 15, 1996. Samples were obtained from within the Loy Yang complex and at the corresponding discharge point at the ash pond. The ash slurry was filtered on site through a 75 µm sieve, separating the water and the ash residue. The water was collected in two bottles, one bottle for calcium, magnesium, sodium, potassium, sulphate, chloride, carbonate and bicarbonate analysis and pH, Total Dissolved Solids, Electrical Conductivity and Redox Potential, and the second bottle with nitric acid preservative for the determination of arsenic, barium, boron, chromium, cadmium, cobalt, copper, lead, mercury, molybdenum, nickel, tin, selenium and zinc concentrations. The ash residue was used for sulphate and chloride analysis.

Samples of dry precipitator ash, or *fresh ash*, were collected from the Loy Yang A complex on March 20 and from Loy Yang B on March 7 and May 7 1996. These samples were collected from the electrostatic precipitators before the ash reached the point in their respective collection systems where the slurry water was added, representing the freshest condition of the ash. The samples were then subjected to a total decomposition analysis for the determination of major constituents and heavy metals. These results were then compared to the slurry water composition and slurry ash.

The soil characteristics (bulk density, moisture content and specific gravity/soil particle density) of the second Loy Yang B dry ash sample were determined according to Australian Standards (AS-1289.C5.1-1977, 1991).

### 3. RESULTS

#### 3.1. Aged Ash Leachability

The results for the acid digest analysis of the 12 samples are found in Table 1. Samples from the sites 1, 5 and 9 showed elevated levels of barium and high levels of mercury, although still within EPA criteria for an acid digestion analysis. The results also show the high degree of variability of the ash across the pond. Consequently, samples from the sites 1, 5 and 9 were chosen for further laboratory investigation.

Samples 1, 5 and 9 were analysed with a total decomposition technique. The results are shown below in Table 2. The samples are all within the clean fill criteria except for significant concentrations of barium.

In a detailed field investigation by Black & Wright (1992) of aged ash composition, a total of 18 samples were collected from the ash pond and analysed. The average mineral composition they found was 44.1% silicon (as SiO<sub>2</sub>), 13.5% aluminium (as Al<sub>2</sub>O<sub>3</sub>), 4.9% iron (as Fe<sub>2</sub>O<sub>3</sub>), 1.8% calcium (as CaO), 5.5% magnesium (as MgO), 1.1% titanium (as TiO<sub>2</sub>) and 0.8% sulphur (as SO<sub>3</sub>). Our results show higher levels of calcium and magnesium, but would most likely be due to different coals over time (high calcium coal was being mined at the time).

*Table 1 : Aged Ash Acid Digestion Analysis (mg/kg)*

Site	Major Ions						Ba	Cd	Cr	Co	Mo	Ni	Sn	Hg
	Ca	Mg	Na	K	SO <sub>4</sub>	Cl								
1	48,000	47,000	13,000	810	6,600	850	550	1.3	18	7.7	11	15	39	1.5
2	23,000	37,000	10,000	980			330	1.2	23	19	9.3	29	34	1.1
3	64,000	47,000	3,100	410	6,500	61	380	0.9	20	18	10	25	38	1.1
5	42,000	33,000	12,000	1,500	4,100	1,000	490	0.8	28	9	12	21	35	2.0
6	3,200	3,200	2,000	210	140	8.40	170	0.6	18	6	9	11	10	0.16
7	6,800	9,600	9,700	1,700	1,500	140	170	0.3	57	12	8	22	21	1.3
8	9,100	10,000	2,700	470			210	0.5	22	9	10	20	19	0.44
9	56,000	46,000	8,300	820	88	<5	440	1.0	27	19	12	32	36	1.2
10	6,100	6,700	3,600	980	1,100		92	0.9	34	7	<5	15	14	0.91
11	2,200	3,400	4,600	1,100	390	66	82	0.1	55	7	5	16	12	0.71
12	12,000	16,000	4,600	790	530	96	180	1.0	39	14	8	23	20	0.67
13	1,900	2,900	4,600	1,200		760	78	0.6	56	7	5	15	12	0.62
EPA <sup>1</sup>							400	5	250	50	40	100	50	2

<sup>1</sup> EPA (Vic.) criteria for classifying contaminated waste (EPA, 1991).

The results of the sequential batch extraction conducted on these samples with both neutral and acidified water are found in Table 3. The results show a low salinity leachate, with barium being the only heavy metal detectable. The first leachate extracted from the aged ash has a TDS of approximately 780 mg/l, being dominated by sulphate, sodium, chloride and calcium. The second leachate has a TDS of approximately 510 mg/l with a similar overall chemistry. Although pH was not determined for this test, a strong alkaline environment can be established through the absence of bicarbonate in the leachates and the high ratio of carbonate to bicarbonate. According to the ASTM standard for sequential batch leaching, there is no requirement to maintain the pH at a constant for the duration of the test. This shows that the aged ash has a strong alkaline buffer and thus dominates the chemistry of the leachates.

Table 2 : Selected Aged Ash Composition

Element	Site			EPA Criteria	Element (mg/kg)	Site			EPA Criteria
	1	5	9			1	5	9	
S (as SO <sub>3</sub> ) (%)	1.13	1.51	2.15		Cr	53	102	79	250
Ca (as CaO) (%)	11.08	9.37	9.37		Co	10	18	29	50
Mg (as MgO) (%)	15.82	11.05	11.70		Cu	41	51	32	
Na (as Na <sub>2</sub> O) (%)	1.75	2.60	1.40		Pb	<50	<50	<50	
K (as K <sub>2</sub> O) (%)	0.13	0.32	0.16		Mo	<10	<10	<10	40
Cl (%)	0.16	0.14	0.02		Ni	34	64	54	100
As (mg/kg)	14	33	22	30	Sn	<3	7	3	50
Ba (mg/kg)	1,362	908	724	400	Hg	0.39	2.15	0.52	2
Cd (mg/kg)	2	<2	<2	5	Zn	154	96	76	

Table 3 : Sequential Batch Leaching on Aged Ash (mg/l)

Site		Na	K	Ca	Mg	SO <sub>4</sub>	Cl	CO <sub>3</sub>	HCO <sub>3</sub>	Ba	TDS
1	A1	380	21	42	0.11	400	80	66	0	0.16	1,200
1	A2	51	5.6	76	0.11	110	8.8	40	0	0.35	400
5	A1	230	13	49	0.06	360	81	120	0	0.13	860
5	A2	16	2.2	93	0.06	110	9.3	120	0	0.29	860
9	A1	140	14	46	0.29	310	2.4	110	0	0.10	360
9	A2	21	5	52	0.43	120	<0.5	45	6	0.16	300
1	W1	330	19	38	0.11	140	54	66	0	0.16	1,200
1	W2	48	5.5	82	0.18	50	8.9	60	0	0.37	420
5	W1	210	12	45	0.09	120	70	160	0	0.14	380
5	W2	14	2.1	89	0.08	50	7.4	130	0	0.27	800
9	W1	150	15	45	0.53	340	2.1	56	5	0.11	680
9	W2	12	3.6	60	0.31	110	<0.5	47	0	0.22	270

Cadmium, chromium, cobalt, molybdenum, nickel, tin and selenium were below detection limits.

It is possible to calculate the total mass leached from each sample and compare it to the total concentration with the following formula :

$$\text{Mass Leached per kg of Aged Ash} = \frac{C_{L1} \times V_{L1} + C_{L2} \times V_{L2}}{\text{Mass of Aged Ash}} \quad \text{mg/kg}$$

where  $C_{L1/L2}$  - concentration in first/second extracted leachate;  
 $V_{L1/L2}$  - volume of first/second leachate sample (2 litres);  
 Mass of Aged Ash - mass used in batch experiments (100 g).

The sequential batch leaching results show that between 1.7% to 2.5% of the ash remains soluble or leachable after 6 to 12 months field leaching in the ash pond. On similar batch tests on Morwell aged ash, Black (1990b) found that with five extractions 12% of the ash was soluble, significantly higher than our results. Given the decrease in concentrations observed in our results and the near 100% leaching of some components, the total soluble mass would not be expected to increase much with further sequential extractions on the aged ash.

By calculating the percentage leached from each test on the three different samples, and then averaging the six results, the following order of leachability can be established :

Cl (71%) > SO<sub>4</sub> (42%) > Na (39%) > K (29%) > Ca (3.3%) > Ba (0.8%) > Mg (0%)

The acidified test showed slightly higher solubilities, due to the initial pH of 4, but the alkaline nature of the ash prevented the leaching of trace metals, except for barium which leached in low concentrations.

The averaged results of the slurry water and ash samples are found in Table 5. They show the transport water to be of moderate to high salinity, with a TDS of approximately 7,100 mg/l. The principle components of the water are sulphate, sodium, calcium and chloride, with minor amounts of potassium and magnesium. The results of sulphate and chloride analysis of the slurry ash (Table 6) show that a general pattern of reduction in soluble mass is occurring in the hydraulic transport system.

Table 4 : Mass Leached and Total Mass of Aged Ash Elements (mg/kg)

Sample									Total
Site	Test	Ca	Mg	K	Na	SO <sub>4</sub>	Cl	Ba	Leached
1	Acid	2,360	4.4	532	8,620	10,200	1,776	10.2	25,612.4
	Water	2,400	5.8	490	7,560	9,400	1,806	10.6	18,033.8
	Total	79,188	95407	1,079	12,982	13,558	1,550	1,362	
5	Acid	2,840	2.4	304	4,920	3,800	1,258	8.4	24,072.4
	Water	2,680	3.4	282	4,480	3,400	1,548	8.2	18,193.4
	Total	66,967	66,640	2,656	19,288	18,118	1,400	908	
9	Acid	1,960	14.4	380	3,220	8,600	48	5.2	17,452.4
	Water	2,100	16.8	372	3,240	9,000	42	6.6	16,940.8
	Total	66,967	70,560	1,328	10,386	25,797	230	724	

### 3.2. Loy Yang Ash - Basic Soil Characteristics

A specific gravity (soil particle density) test was performed on the second sample of Loy Yang B precipitator ash, according to Australian Standard AS-1289.C5.1-1977. The test was completed with water and kerosene as the fluid medium. It showed the fresh ash particles to be quite dense, with a specific gravity of 3.24, but a very loose and highly porous material overall with a free flow bulk density of 626 kg/m<sup>3</sup> and a porosity of 81.2%.

Field investigations by Geo-Eng have shown the dry density of ash in the disposal pond to range between 450 to 990 kg/m<sup>3</sup>, with an average of 600 kg/m<sup>3</sup> (Kacavenda, 1994). The ash was also shown to be a fine, silty material with an average of 66% finer than 75 µm. Field permeability values have been determined to be 3.5×10<sup>-6</sup> m/sec.

Table 5 : Average Slurry Water Chemistry

(all mg/l)	TDS	Ca	Mg	Na	K	SO <sub>4</sub>	Cl	Alk.	pH
Loy Yang A	7050	411	71	1800	72	3970	98	141	10.3
Loy Yang B	11000	470	115	2800	130	6050	875	140	10.7

  

(all µg/l)	As	Ba	B	Cu	Pb	Hg	Mo	Se	Zn
Loy Yang A	9	70	3,500	61	51	1	61	289	109
Loy Yang B	1	90	4,950	70	95	1	80	63	45

Cadmium, chromium, cobalt, nickel and tin were below detection limits.

Table 6 : Slurry Ash - Sulphate and Chloride Levels (mg/kg)

No.	Date	Site	Sulphate			Chloride		
			Inlet	Outlet	%Diff.	Inlet	Outlet	%Diff.
1	29-2-96	LYA	12,000	7,300	-39.2	2,000	960	-52
2	5-3-96	LYA	5,500	10,000	81.8	540	620	14.8
3	7-3-96	LYB	22,000	23,000	4.5	2,200	1,400	-36.4
4	12-3-96	LYA	18,000	6,300	-65	1,100	510	-53.6
5	15-3-96	LYA	9,000	8,100	-10	840	960	14.3

#### 4. DISCUSSION AND ANALYSIS

Based upon the permeability values from field and laboratory tests, the chemical results from the slurry ash samples, and the sequential batch leaching results, it is possible to develop a simple physical model of the ash leaching in the disposal pond. The initial leaching is occurring within the hydraulic ash transport system, primarily due to the intense mixing and shaking during travel to the discharge point. Over the next 6 to 12 months, it possible that water could travel at a velocity ranging from 10 to 110 m m/year, based on field and laboratory permeability values. This represents quite a significant flow of water through the ash. Given that the ash is expected to be deposited in the pond at a rate of 4 m/year, the above values could represent between 13.5 to 27 pore volumes of field leaching of the ash in the disposal pond. Although no column tests have confirmed the point where Loy Yang ash reaches steady state, other research work at Morwell (Black, 1990b) and Yallourn (Black, 1990a) has shown that low salinity, steady state leachates are achieved from approximately the fourth pore volume of water moving through the ash. The above analysis confirms that the aged ash, deposited within the disposal pond for 6 to 12 months, has reached this steady state point and can be considered to have a low potential for impact on groundwater when excavated from the pond and disposed of in the overburden dump. It should also be pointed out that batch tests, where the material is shaken overnight, represent a *worst case scenario* of leaching. Such vigorous mixing would not occur in the field and consequently the leachates to be expected in the field would have a lower salinity for a longer period of time.

## ACKNOWLEDGEMENTS

Authors extend their gratitude to Australian Research Council, Loy Yang Power Infrastructure Services and Geo-Eng Pty Ltd. for supporting the project. The support rendered by Dr Domenic Caridi and Mr Jason Beard (Dept. of Chemistry and Biology, VUT) in conducting the sequential batch leaching experiments and Md Fashiur Rahman in conducting the permeability tests is greatly appreciated. The support of Mr Ian Soutar and Mr Russell Pentland in collecting the aged ash samples is also gratefully acknowledged.

## 5. REFERENCES

American Society for the Testing of Materials (ASTM); 1994; *"1994 Annual Book of ASTM Standards"*; Section 11 - Water and Environmental Technology; Volume 11.04 Pesticides, Resource Recovery, Hazardous Substances and Oil Spill Responses, Waste Management, Biological Effects.

Standards Australia; 1991; *"AS 1289.C5.1-1977 Determination of the Soil Particle Density of a Soil (Standard Method)"*; Australian Standard 1289.0 "Methods of Testing Soils for Engineering Purposes".

C. J. Black; 1990a; *"Yallourn W Ash Leaching"*; State Electricity Commission of Victoria; Report SC/90/174.

C. J. Black; 1990b; *"Leachability of Morwell Brown Coal Ash"*; M. App. Sci. (Env. Eng.) Thesis; Dept. of Chemical Engineering, University of Melbourne.

C. J. Black & B. Wright; 1992; *"Comparison of Latrobe Valley Ash Pond Sediments"*; HRL Technology Pty. Ltd., Report CO/91/473.

K. M. Bone & H. A. Schaap; Feb. 1980; *"Solubility of Minor and trace Elements in Brown Coal Ash : A Preliminary Study"*; State Electricity Commission of Victoria; Report SO/80/4.

EPA Victoria (1991), Information Bulletin WM91/01, Off-site Disposal of Contaminated Soil.

S. Kacavenda, Jan. 1994, *"Loy Yang Ash Pond - Geotechnical Properties of Ash : Preliminary Investigation"*; Geo-Eng Pty. Ltd., Report 1231/2.

S. Kacavenda & T. McKinley, June 1994, *"Loy Yang Ash Pond - Geotechnical and Environmental Aspects of Ash Disposal into the Overburden Dump"*; Geo-Eng Pty. Ltd., Report 1248/4.

T. J. Mantyvirta & S. Clancy, 1989, "Report on Additional Ash Storage Options for Loy Yang Power Station"; State Electricity Commission of Victoria, Geotechnical and Design Division, Design Engineering and Environment Department, Report No. GDD 22.

T. McKinley; 1995; *"Loy Yang Ash Pond Leached Ash Quality"*; Geo-Eng Pty. Ltd., Report 1324/10.

D. Strudwick; 1994; *"Draft State Environment Protection Policy (Groundwaters of Victoria)"*; Environment Protection Authority (Victoria); Publication No. 288.