

Ash Utilisation – an Australian Perspective

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Abstract

Australian producers and marketers of power station ash formed the ADAA (Ash Development Association of Australia Inc.) in 1991. The primary objectives are to conduct research and technology transfer on behalf of members and to assist in developing market opportunities in the use of ash materials.

In achieving these objectives, the ADAA has sought to increase user awareness of the benefits arising through effective utilisation of this valuable industrial mineral resource; which if realised, has benefits for industry, the environment and the community as a whole.

Ash produced during 2002 approximated to 12.5Mt (million tonnes) for Australasia (Australia & New Zealand). From the total ash produced, some 4.1Mt has been effectively utilised. The main contributors are; cementitious applications at approximately 1.35Mt, non-cementitious applications at 0.47Mt, with the balance of 2.28Mt used in projects offering some beneficial application (i.e. mine site remediation and for the construction of local haul roads). These applications and growth potentials will be discussed.

The challenge for the membership ahead is identifying the next incremental step (growth potentials) for increased utilisation of domestic Ash production. The industry sectors participating in the use of ash materials will be discussed, including new areas requiring greater research and investment.

1. Introduction

Coal fired power stations around the world produce enormous quantities of power coal ash or internationally known as Coal Combustion Products (CCP's) every year. Whilst volumes continue to grow consistent with increased consumer and industry energy demands the ADAA can demonstrate that generators and marketers of coal ash are making significant inroads into increasing effective utilisation of its portion of the total worldwide coal ash production.

In an increasingly energy hungry society any small achievements of increased utilisation of CCP's could quickly become dwarfed. Current coal reserves are estimated to last for another 200 years with gas and oil reserves estimated to last between 50 –65 years (WCI 2003). Many countries have signaled their intentions to continue the use of coal as a viable long term and sustainable energy source. Given the continued long term availability of coal and the need to maximise return on capital investment in installed coal fired power generation capacity, an abatement in coal use in power generation and consequently CCP production would seem unlikely. Our challenge is to find "acceptable" and "beneficial" uses for ash materials.

One example that highlights an increasing dependency on coal-fired power stations would be the case of the Japanese Government. With increasing pressure from environmental groups and industrial incidents concerning the re-treatment of radioactive materials, the Government has moved to reduce the planned construction of 20 nuclear power stations, leading to increased reliance on power generation from coal fired power stations for the next 30 years (CCUJ 2000).

Australia represents a similar scenario to many industrialised nations where there is significant dependency on coal-fired power stations for power generation. Current installed capacity operating as coal fired power stations stands at approximately 84% of total power generation for the nation. Based on present installed capacity (ESAA 1999), national electricity demand growth estimates and proposed new capacity (AGO 2000), ash material availability is expected to increase at around 3-5% annually.

For Australian ash producers, increasing the "effective utilisation" of ash materials is fast becoming a large priority and huge challenge in the face of deregulating electricity market places. Open contestability of electricity supply markets has presented power station operators with many challenges not limited to reducing costs and increasing profitability. Coupled with the remaining majority of generation, capacity is poised for transfer from Government ownership to private sector control, a number of previously "taken for granted" political protections afforded to these Government Trading Enterprises (GTE's) may soon disappear.

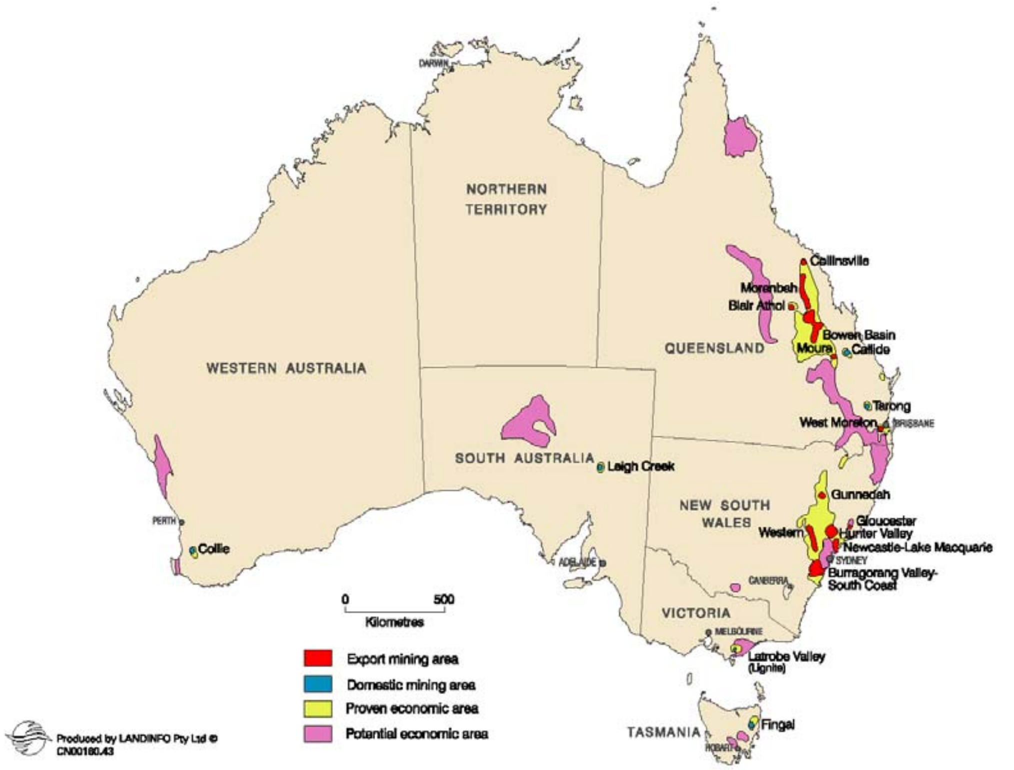
In summary, ash is but one part of the business outputs that has excellent return potentials if management considers prudent commitment and investment, both in time and financial resources.

2. Ash Produced in Australia

A wide range of thermal coals (also known as energy, power, steam or steaming coals) are available from Australian producers, see **Figure 1**. The coal industry in Australia can meet the requirements of most consumer thermal coal needs.

Typically Australia has coals high in energy content but low in sulfur and other contaminants. Australian thermal coal is typically high in calorific value (energy content), has moderate ash levels and is low in sulfur and heavy metal contents. Export coal is low in ash but locally used coal is quite high, and probably much higher than any Northern Hemisphere coals.

Figure 1. Coal Regions of Australia



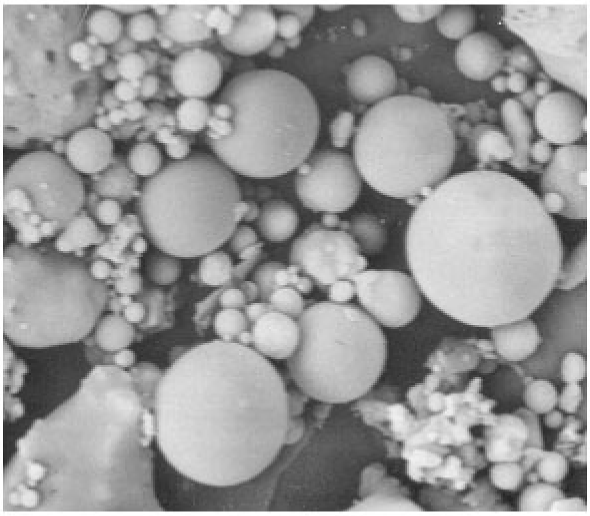
The composition of CCP's in Australia can vary significantly depending on coal type, source and generator plant age and type. For example, brown coal (lignite) from the Latrobe Valley region is mainly used in Victorian coal fired power stations results in a very different CCP's from that of black coal as might be expected.

In addition, other in-process factors will also impact on the final characteristics of CCP's produced from these power stations. In the main, the milling plant design and operation as well as furnace type influences the differences. Regions that generate almost 80% of ash materials are located on the eastern seaboard in relative proximity to major markets.

Typical fly ash material properties

The fly ashes produced in Australian power stations are light to mid-grey in colour and have the appearance of cement powder. Particle sizes range from less than 1 µm (micrometer) to 200 µm and are irregular to spherical in shape.

Figure 2. SEM image of fly ash



The majority of fly ash produced in Australia is categorised as F type – being mainly silica and alumina (80-85%). F type ash is pozzolanic and reacts with various cementitious materials. About 85% of the current beneficial use of fly ash is to enhance the properties of concrete and other building materials, and used to good effect with road base binders and asphalt filler.

Table 1. Principal chemical constituents of Australian coal fly ashes as percentages

Fly Ash	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	L.O.I
A	58.0	26.5	3.2	1.6	0.9	0.4	0.4	0.1	3.0
B	56.7	26.7	5.0	1.1	0.9	0.4	1.3	0.1	3.5
C	63.2	27.4	1.0	0.2	0.2	0.6	2.2	0.2	10.0
D	69.2	21.8	3.5	1.2	0.7	0.5	1.4	0.1	1.3
E	58.6	28.5	6.3	1.6	1.0	0.3	1.2	0.7	1.3
F	65.0	23.0	5.0	0.2	0.3	0.4	1.8	0.2	1.3
G	59.0	26.4	3.3	5.9	1.8	3.7	0.7	0.1	0.2
H	48.1	30.3	12.2	3.2	1.5	0.4	0.5	0.2	2.0
I	62.4	26.8	1.9	1.6	1.1	1.0	0.7	0.3	2.1
J	71.0	24.9	0.7	0.1	0.2	0.1	0.4	0.0	1.1
Mean	**61.1**	**26.2**	**4.2**	**1.7**	**0.9**	**0.8**	**1.1**	**0.2**	**2.6**
Std Dev	**6.62**	**2.48**	**3.31**	**1.74**	**0.54**	**1.05**	**0.62**	**0.19**	**2.78**

Fly ash has strength and compressive properties resembling a medium to dense sand but its compacted mass is only about 60% of that of dense sand. Fly ash has therefore been ideal for backfilling retaining walls or construction embankments over soft soils because of its:

- high internal angle of friction
- low unit mass
- low compressibility
- reduced settlement when used as fill material

- ease of compaction

Typical bottom ash material properties

Bottom ash and boiler slag are formed when ash adheres as hot particles to the furnace walls, agglomerates and then falls to the base of the furnace where it is collected for disposal. The chemical composition of typical bottom ash is shown in the Table 2.

Bottom ash and boiler slag comprise approx 10 to 15% of the total CCP's produced and range in grain size from fine sand to coarse lumps. They have chemical compositions similar to fly ash, but may contain greater quantities of carbon and are relatively inert because they are coarser and more highly fused than fly ash. Accordingly, these materials are not highly pozzolanic in nature and are less suitable for use in cement and concrete products.

They are however, very suitable for structural fills, asphalt mixes and civil engineering applications. In recent years agricultural applications have increased in volume as awareness of the materials free draining properties have become known.

Table 2. Principal chemical constituents of Australian coal bottom ashes as percentages

Bottom Ash	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Mn_2O_3
A	61.0	25.4	6.6	0.8	1.5	1.0	0.9	0.2	0.1
B	59.3	20.9	4.3	2.0	4.7	1.6	3.0	0.4	0.1
Mean	**60.2**	**23.2**	**5.5**	**1.4**	**3.1**	**1.3**	**2.0**	**0.3**	**0.1**
Std Dev	**1.20**	**3.18**	**1.63**	**0.85**	**2.26**	**0.42**	**1.48**	**0.14**	**0.00**

3. Ash utilisation in Australia

Real achievements through co-operation

The ADAA mission is to foster the increased “effective utilisation” of coal ash through the promotion of the environmental, economic and technical advantages, to the benefit of member's, industry and the community.

Although being a relatively young (formed in 1990) and small association (14 Full Members and 8 Affiliate Members) operating a part time secretariat with specialist consulting firm (HBM Group Pty Ltd) compared with our overseas equivalents, the ADAA takes great comfort with its achievements, in particular, the area of increasing CCP utilisation since its inception.

By way of demonstration, a comparison between US and Australia can assist in understanding the differences in relative volumes and market sizes, whilst providing some meaningful comparison in effective utilisation of CCP's. For the US in 1991, 30.8 percent of 88 million tons was used, or 27 million tons; in 2001, 33.4 percent of 117 million tons, or 39 million tons (Schwartz 2003), whereas for Australia in 1991, 9 percent of 8.1 million tonnes was used, or 0.7 tonnes; in 2002, 32 percent of 12.5 million tonnes, or 4.1 million tonnes in 2002 (ADAA 2003).

Further to these results, when comparing each respective countries population divided by the beneficially used component will distill out some understandable indicator. Tables 3 shows converted US Ton (short) into metric tonne for some meaningful comparison. In summary the results show that for every person in the US 122 kgs of CCP's are beneficially used, whereas for Australia some 216 kgs of CCP's are beneficially used for each person. This results in an almost 98 percent greater effective utilisation for Australia.

Table 3. Comparison of effective utilisation between US and Australia

Year 2001	US tonne	Aus tonne
Production	106,140,610	12,000,000
Population	290,000,000	19,000,000
Benefically used	35,380,203	4,100,000
Kgs/person	122	216

The formation and operation of the association has lead to significant achievements for members, in particular, two fold (100 percent) increase for CCP use in various effective applications over the period 1991 to 2002. Total CCP sales (excluding beneficial use) have grown at around 10 percent annually, with these materials being mainly used in construction industry sectors. Whereas in the period between 1981 to 1990 (prior to the ADAA formation) sales of CCP's increased only 35 percent for the 10 year period (ADAA 2003).

Results such as these discussed above highlight the benefits associated with industry participants and channel members working together through an industry association to the mutual benefit of all stakeholders.

A sustainable industry segment is born

CCP production for the calendar year 2002 approximated to 12.5 million tonnes (Mt), with 4.1Mt said to have been "effectively utilised", defined as CCP's sold or used in applications for some beneficial use. It is estimated the sales component of CCP's are worth between $90-100 AUD million.

Figure 3 presents a twelve (12) year snapshot of CCP production and utilisation, which includes fly ash and bottom ash material. Area coloured orange represents CCP placed in storage for each year. The green area represents CCP's used in some beneficial application. The cream area represents sales of CCP's for both fly ash and bottom ash. The main contributors to total ash sales in 2002 were cementitious and non-cementitious applications.

The main applications (by volume) represented in the 1.35Mt of CCP sales are:

- Pre-mixed concrete
- Road stabilisation
- Blended cement products

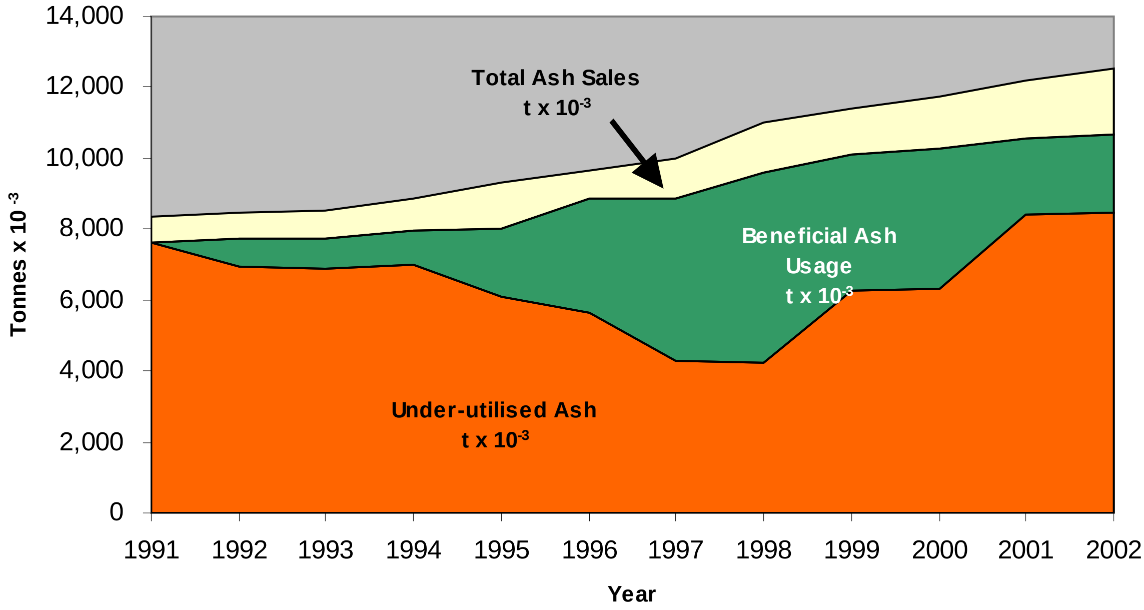
- Controlled low strength fills
- Asphaltic fillers
- Under ground mining applications
- Agricultural uses

Members are annually surveyed for production, sales and beneficial use of CCP's. This data is overlayed with annually reported coal consumption figures for generators around the country to calculate total CCP production.

Membership surveys are based on the following broad reporting categories,

1. Category 1 – Ash materials sold for the use in cement production, blended cement manufacture, binder supplement.
2. Category 2 – All uses not included in Category 1 or 3. This includes ash sold for use in road stablisation, asphaltic fillers, controlled low strength material and bulk fill, where a small amount of cement is added as a stabiliser.
3. Category 3 – All uses of ash where no other binders are added to the ash, e.g. Bulk fill, road bases non-stabilised, agricultural applications.
4. Beneficial use – Use of ash in projects where benefits could have resulted in reduced direct handling costs, used in an in-kind nature to the benefit of external or internal groups, e.g. Mine site remediation, void backfilling, site haul roads. Placement in ash pond is not considered a beneficial use.

Figure 3. Ash utilisation 1990 to 2002 by use



Source: (ADAA 2003)

5. Barriers to be overcome – many fronts

There continues to be a keen focus on the continued growth of effective utilisation of ash materials, in particular increasing the ADAA capability to confront many regulatory, economic, social and technical challenges for CCP use, industry members must remain focused in the years ahead.

A change in our industry ownership structure, resulting from the general trend of State Governments reducing their ownership and resultant management of public infrastructure, represents a major uncertainty. Associated factors with privatisation of power stations comes the transfer of a number of wide ranging environmental obligations on these new private business. In other words these could become new cash cows to government revenue. This change is a very real threat for operators once Governments are free of their financial, operational involvement in these assets.

The ADAA recently completed an extensive review of Commonwealth (Federal) and State legislation; *Coal Ash: A Review of Legislation and Regulations within Australia*, *2003.* This review has been used to assist member companies in understanding the benefits of adopting a proactive position on these issues, moreover, those that relate to the environmental legislation and regulation, and work towards demonstrating to policy makers the missed opportunities of poorly considered legislation, which contributes towards under utilisation of ash materials as valuable resource (Aynsley, Porteous et al. 2003).

5.1 Regulatory

Today in Australia, a number of barriers still exist in the area of regulation with various government authorities and agencies adopting outdated and closed minded approaches towards material classification, transportation and material storage prior to sale.

Interpretations of the current legislation across Australia suggest that, regardless of any recycling process a waste material may be subjected to, it (ash) will still be considered a waste. This can mean ash will be subject to environmental controls beyond those of equivalent virgin materials that may have equal potential for environmental impact. This position is inequitable from a market perspective and will clearly result in virgin materials being used in preference to alternative materials.

The report found *“Australia is a federation of states which occasionally leads to dislocation between Federal and State sourced laws. The utilisation of coal ash and other products - particularly for agricultural amelioration - has recently come under scrutiny and highlighted both an absence of, as well as internal conflict in existing legislation.”(Aynsley, Porteous et al. 2003)*

The fragmentation and or lack of state based regulation from key agencies such as the Environment Protection Authorities (EPA) and various State Road Authorities is a significant hindrance. These agencies need to consider adopting more consistent approaches to business that produce, process, transport and ultimately sell these materials. For example, each State operates under its own Environment Protection Act and operational regulations. Classification of CCP’s can vary widely with one state regulation determining ash as “inert waste” while it becomes a “prescribed waste” in another state. Given material properties are considered consistent for the purposes of practical use under Australian Standards building classification; it is difficult to comprehend how these opposing views can continue. With ash materials regularly moving intrastate for commercial use, clearly greater coordination between state agencies is an essential requirement to remove state bias. Groups such as the National Environment Protection Council (NEPC) afford an excellent model where representatives of various state agencies meet to ensure that legislation is adopted across borders in a unilateral fashion.

5.2 Economics

The economics of ash production, processing, logistics and finally to effective utilisation represents a long and complex value chain, which is influenced by many variables and subsequent barriers. Each of these aspects justifiably warrant a separate paper for discussion, however is beyond the scope of this paper.

The discussion will focus on the important medium and long-term consideration which needs to be placed on current costs versus future benefits model. Before exploring these issues related to new value created in the effective utilisation of CCP's, we must be mindful of the fundamental economic factors governed by "supply and demand" and how they affect current and future uses.

Given surplus CCP materials are readily available (supply), some have moved to push more materials into currently accepted product categories, without much consideration of the net effects. Case in point for the categories of pre-mixed concrete demand for ash is "inelastic" i.e. changes or fluctuations in price or availability of ash to increase use will have little effect on increased volumes or sales as demand is derived by other factors - demand for new structures using concrete etc.

There is however, some room for increased blending percentages beyond current practices, which in turn increases total ash volumes – but overall growth is limited to the construction sectors use of concrete and will never consume available surplus materials.

Areas of elastic demand or new demand for CCP's are those of possible product substitution, for example agricultural research indicates significant benefits can be derived in soil amended with CCP's. Traditional synthetic fertilizers although providing additional nutrient values to the soil, do not provide some of the physical benefits such as improving body of poor or weak soils to retain moisture for plant take up (Pathan, Colmer et al. 1999).

Based on the international literature, this product application represents an opportunity for significant volume increase if CCP's could be proven to have some economic benefits, however at a much lower return per unit value problems arise. Potential marketers of CCP's for agriculture seem reluctant to embrace these avenues, whilst generators supportive of investigating alternative uses are concerned about long term investment required to produce an economically sound business case for use.

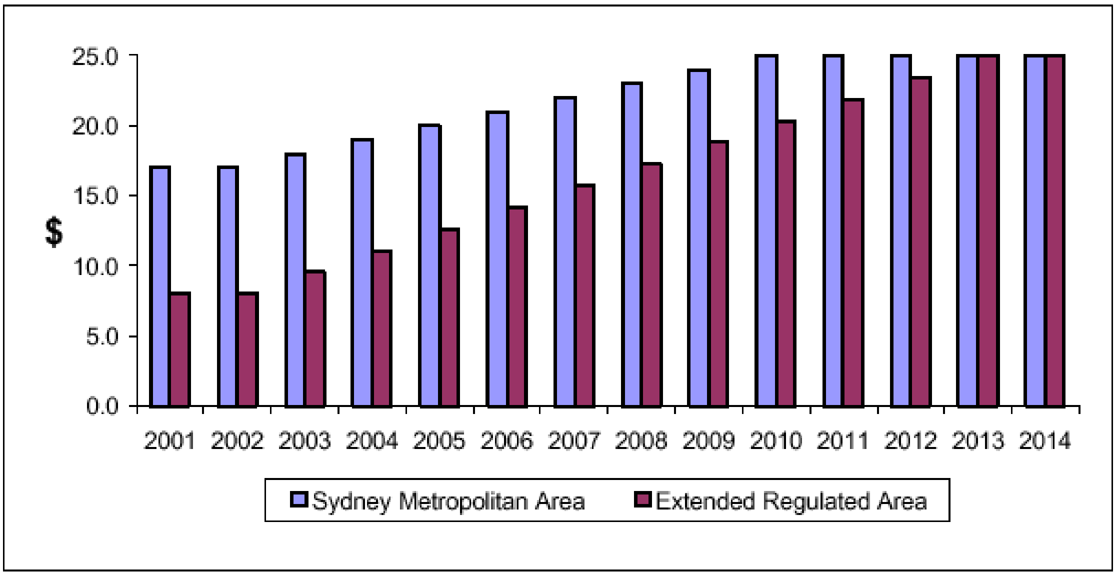
Although the *least cost* approach is fiscally sound for the short term, this focus denies the opportunity to reduce real long-term risk associated with this strategy. An example which highlights future exponential cost increases is that of the NSW Government and its review of the Waste Minimisation and Management Act 1995.

This Act was the first to target wastes and generation sources, establishing a number of goals focused on reduction, management and reuse. Moreover it placed additional cost burdens on un-sustainable business practices engaged in the disposal of wastes (NSW Government 2001).

The previous Act had avoided difficult decisions related to wastes generated from industries such as Steel and Power, in particular the waste management and associated levies on disposal. Ash ponds and slag heaps were exempted. In the recent review of the Act, this position has changed, and potential cost increases on materials placed within the operation site could apply.

It has been proposed that a $25/tonne levy in both the Sydney metropolitan area and the extended regulatory area is to be reached over phase-in periods of 2002-09 and 2002-12 respectively, starting 1 July 2002. This would involve annual steps of $1 per tonne for the Sydney metropolitan area and $1.50 per tonne for the extended regulated area (NSW Government 2001). The effect of such a levy can be seen graphically in Figure 4.

Figure 4. Proposed waste levy increase for NSW.



The next steps that needed to be taken, came into effect 1 July, 2002.

> *Increase the levy in moderate amounts over the medium term to support reprocessing and recycling of resources and reduce waste disposal. Amend section 88 of the Protection of the Environment Operations Act 1997 (Contributions by licensee of waste facility) to give the Environment Protection Authority discretion to waive levy contributions in limited circumstances.*

Estimates from producers put total cost to emplace ash onsite at around $4 00-$5.00/tonne. Looking beyond current operation costs and annual CPI increases, these businesses would become unviable if the above model were to become a reality in NSW, and subsequently across other states. A levy based on current under-utilised ash volumes of 6Mt per annum would place an impost of approximately $150 million as at 2003. Presently this proposed levy system has not been extended to include ash.

6. Potential developments for Australia

Potentially very large volumes of CCP's can be used in manufacturing special slurries for diaphragm walls and land reclamation, in underground mining, in special grouts, and for the encapsulation of hazardous wastes, in the production of light weight aggregates, for soil amendments and for the decommissioning of under-ground fuel tanks where it is impractical to remove.

We will briefly cover some of the currently supported alternatives including future inorganic polymers (IP) uses.

Lightweight Aggregates

As mentioned, Australian ash has relatively low carbon content (usually less than 5% by mass of fly ash). Fly ash with carbon content of between 7-10% has been used in the UK and Europe as a raw material in manufacturing lightweight aggregate for concrete, a product known as Lytag.

In the Lytag process, the fly ash is fed onto pan pelletisers, where the rotation action converts damp ash into spherical pellets. The pellets are then passed to the sinter strand, where they are fused at temperature of approximately 1300°C. Carbon in fly ash is ignited, producing gas and increasing the pellet size, which, upon cooling, solidifies to strong and lightweight particles. Lytag, or similar processes for making lightweight aggregate from fly ash, is currently being considered as an integral part of total fly ash management approach in Australia.

The ADAA has recently signed a memorandum of understanding with the CCSD (Cooperative Research Centre for Coal in Sustainable Development). The CCSD manage a research program, Program 6 - 'By-products and waste', which has the objective to 'provide research that addresses environmental issues associated with waste management and opportunities for waste utilisation.'

Currently the ADAA and CCSD are collaborating to develop a strong business case for future research into the manufacture of aggregates from CCP's available in Australia.

Light weight brick manufacture

Fly ash with carbon content in excess of 10% (with no upper limit) can be used as a raw feed in lightweight brick manufacturing. As in the Lytag process, carbon acts as a fuel, and the generated gas inside a fired brick forms spherical voids, resulting in a strong, lightweight block, with excellent thermal-insulating properties. Work at the University of Wollongong indicates that considerable savings in brick kiln fuel demand can be made using high carbon content fly ash.

Given the very small volume of high carbon ash available in Australia this project has not progressed at this stage.

Fly ash soil amendments

The use of fly ash to amend sandy soils has been ongoing project since 1998 and concluded in 2002. The project assessed the improved water and nutrient use properties of CCP's at the University of Western Australia.

The key research questions were – the effect of fly ash as a soil addition for turf farming, measuring:

1. Changes to water and nutrient movement in the soil

2. Impact of the changes on water use

3. Possible adverse effects of fly ash use (e.g. potential release of heavy metals).

This work is part of the on-going nine (9) years of research into uses of fly ash and furnace ash by the Ash Development Association. Results of the studies have been evaluated from field plots during 1999, 2000 and 2001.

The major findings have demonstrated improve crop yields, increased turn around time for turf farming harvests, improved growth colour and general health, improved water take up and reduced watering requirements.

During the course of 2003 the ADAA conducted a major evaluation of its now nine (9) years of research into CCP use in agriculture to determine the next steps to be taken. In light of the fundamental and reassuring findings the ADAA has committed to funding a second phase research project for the next four (4) years.

This project will undertake very important extension work with the overall aim of the project to develop information, which can be used to demonstrate the cost/benefits of various applications of ash amendments in horticultural and agricultural systems.

These include, potential for particle migration and surface erosion (i.e., possible off-site movements), trace element loadings to soils and long term fates of these elements, long-term evaluation of the persistence of beneficial changes in soil properties in the field, data on properties of a wider number of sources of coal ashes available in Australia, performance of other agricultural crops grown on amended soils and optimisation of fertiliser agronomy for crop production on amended soils.

Moreover, the project will be required to produce industry guidelines and technical data sheets to be used by industry participants when considering the use and application of ash materials.

7. Conclusion

Ash producers, marketers, regulators and current end users face a number of significant challenges ahead. Factors such as large quantities of under-utilised ash materials produced in regions isolated from major markets coupled with poorly coordinated legislation, places great hurdles in front of industry participants to overcome.

We believe, given a strong vision coupled with good management and fiscal commitment from producers (as the major stakeholders in ash), along with a well-targeted promotional program will help realise the benefits associated with effective ash utilization.

We are keenly positioned to embrace new emerging commercially viable uses for ash materials and to further improve our Australian experience for the future utilisation of ash.

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