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INTERNATIONAL COAL COMBUSTION PRODUCTS GENERATION AND USE

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ABSTRACT

This paper describes production and utilization of coal combustion products (CCPs) in many countries of the world. CCPs represent inorganic residue materials left after combustion of coal in conventional and advanced clean-coal technology combustors. These include fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) products from pulverized coal and advanced clean-coal technology combustors. Although 560 million tonnes (Mt) of fly ash, bottom ash, and boiler slag were produced in the world in 1989, only 90 Mt of this (16% of the total) was utilized [1, 2]. In 1992, based on available data, over 370 Mt of fly ash and 90 Mt of bottom ash and boiler slag were produced in the world; and, about 150 Mt (33%) were utilized [3]. In 2000, over 60 Mt of CCPs were produced in Europe and about 95% was utilized [4]. Production and utilization of CCPs in some countries in 2000 were as follows: Canada, 8 Mt, 23%; India, 90 Mt, 13%; Israel 1.3 Mt, 98%; Japan, 10 Mt, 84%; and Turkey, 20 Mt, unknown % [5]. In 2001, USA produced about 110 Mt of CCPs and about 32% was utilized [6].

Keywords: Coal combustion products, fly ash, bottom ash, boiler slag, spray dryer absorbent (SDA) ash, flue gas desulfurization (FGD)

INTRODUCTION

Coal is used as a major source of energy throughout the world. In order to efficiently produce energy, pulverized coal is generally burned. During the combustion process, the volatile matter and carbon burn off, and the coal impurities such as clay, shale, quartz, feldspar, and other minerals mostly fuse together and remain in suspension [7]. These fused particles are carried along with the flue gases. As the flue gases approach the low temperature zones, the fused substances solidify to form predominately spherical particles which are called fly ash. The remaining matters, which agglomerate and settle down at the bottom of the furnace, are called bottom ash. Fly ash is captured by mechanical separators, electrostatic precipitators, or bag filters. It is a mixture of particles varying in shape, size, and composition. These particles can be classified as thin-walled hollow spheres and their fragments, magnetic iron containing spherical particles, glassy particles and unburnt coal [8, 9, 10, 11]. Size of spherical fly ash particles is found to lie in the range of 1 - 150 μm [10, 11].

Coal-Combustion Products

Coal-fired power plants derive energy by burning coal in their furnaces. These power plants generally use either pulverized-coal-fired furnaces, cyclone furnaces, or advanced clean-coal technology furnaces. The ash collected from pulverized-coal-fired furnaces is fly ash and bottom ash. For such furnaces, fly ash constitutes a major component (70 to 90%) and bottom ash component being in the range of 10 to 30%. The combustion of coal in cyclone furnaces occurs by continuous swirling of the coal in a high-intensity heat zone. This causes fusing of ash particles into a glassy slag along the furnace wall, which drops to the bottom of the furnace. The boiler slag constitutes the major component of the cyclone boiler by-product (70 to 85%). The remaining combustion products exit along with the flue gases. Clean-coal ash is defined as the ash derived from plants involving the use of SO_x and NO_x control technologies. Clean-coal ash is typically dry-collected FGD material, e.g., spray-dryer ash.

ASTM C 618 categorizes coal combustion fly ash into two classes: Class F and Class C. The Class F fly ashes are normally generated due to combustion of anthracite and bituminous coal. The Class C fly ashes are produced due to burning of lignite and subbutiminous coal. Most fly ashes are rich in SiO_2, Al_2O_3, and Fe_2O_3, and contain significant amounts of CaO, MgO, MnO, TiO_2, Na_2O, K_2O, and SO_3. ASTM Class C fly ashes (high-lime fly ashes) typically contain 10 to 40% CaO, and Class F fly ashes (low-lime fly ashes) generally contain less than 10% CaO. Due to high CaO content, Class C fly ashes participate in both cementitious and pozzolanic reactions whereas Class F fly ashes predominately participate only in pozzolanic reaction during the hydration process. Therefore, Class C fly ashes are classified as cementitious and pozzolanic admixtures/additives and Class F fly ashes as normal pozzolans for use in concrete.

Fly ash is a heterogeneous mixture of inorganic particles, varying in shape, size, and composition. Fly ash is predominantly composed of spherical glassy particles, which can be less than 1 µm to more than 1 mm in size. The surface area of fly ash ranges between 300 to 500 m^2/kg. Generally, density of fly ash varies between 1.6 and 2.8 g/cm^3.

Bottom ash particles are generally non-spherical, and are typically composed of particles ranging from 2 µm to 25 mm in size. Bottom ash particles could be rounded in shape but are generally angular. They usually have porous structures. The specific gravity of bottom ash varies between 2.1 and 2.7, dry bulk density between 720 and 1600 kg/m^3, and absorption between 0.8 and 2%.

Boiler slag particles are generally non-spherical and are typically composed of particles ranging from 2 µm to 15 mm in size. Boiler slag is composed of angular particles with a glassy appearance. The specific gravity of boiler slag varies between 2.3 and 2.9, dry bulk density between 960 and 1440 kg/m^3, and absorption between 0.3 and 1.1%.

Traditionally, wet scrubbers, Flue Gas Desulfurization (FGD) systems, have been used to control power plant SO_2 emissions and they produce powdered by-products, sometimes up to 10% moisture content. The residue from such systems consists of a mixture of calcium sulfite, calcium sulfates, and fly ash in water. Depending upon the sorbent used, the sulfites and sulfates may be sodium or magnesium-based. More recent FGD systems can also convert the calcium sulfite to calcium sulfate (gypsum).

Recent increased concern over SO_2 emissions from power plants has resulted in development of several advanced SO_2 control systems that produce dry products [12]. These new processes avoid the complexity and operating problems encountered in handling large volumes of liquid or semi-liquid wastes produced in the case of FGD systems. In addition, dewatering is not needed prior to utilization or landfilling. However, costly sorbent materials may be needed for theses process. The advanced systems include Atmospheric Fluidized Bed Combustion (AFBC), Lime Spray Drying, Sorbent Furnace Addition, Sodium Injection, and other clean coal technologies such as Integrated Coal Classification Combined Cycle (IGCC) process. The products generated by these processes have some physical and chemical properties significantly different than those of conventional coal ashes.

The AFBC process produces coal ash, sulfur-reaction products, and calcined limestone reaction products. The sulfur-reaction products are primarily composed of calcium sulfate and calcium oxide. The calcined limestone reaction primarily forms calcium sulfate. The chemical composition of the AFBC ash is similar to that of Class C fly ash except SO_3 and SiO_2 contents. AFBC SO_3 content is higher and SiO_2 content is lower relative to conventional Class C fly ash.

The spray dryer absorbent (SDA) by-products consists of primarily spherical fly ash particles coated with calcium sulfite/sulfate, fine crystals of calcium sulfite/sulfate, and unreacted sorbent composed of mainly $Ca(OH)_2$ and a minor fraction of calcium carbonate. The spray dryer by-products are higher in concentrations of calcium, sulfur, and hydroxide, and lower in concentrations of silicon, aluminum, and iron compared to a conventional Class C fly ash.

The Lime Furnace Injection (LFI) products consist of ash, calcium sulfite and sulfate, and unreacted lime. Products generated by LFI contain 40 to 70% fly ash, 10 to 35% calcium sulfate/sulfites, and 15 to 30% free lime by weight.

The calcium injection process produces products similar to that of LFI and calcium spray-dryer because of similarities in sorbents and injection methods used.

The sodium injection process differs from the calcium injection in regards to type of sorbent used. This process uses a sodium-based sorbent such as sodium bicarbonate, soda ash, trona, or nahcalite [13]. Products generated by this process include fly ash particles coated and intermixed with sodium sulfite/sulfate, and unreacted sorbent.

The IGCC process produces products similar to the other SO_2 control processes.

From the above description, it is clear that most SO_2 control processes generate a by-product (clean-coal ash) similar to that of conventional fly ash. However, addition of sorbent modifies fly ash to a significant extent. The modified fly ash contains fly ash particles coated with sorbent and sorbent-reaction products, and smaller non-fly ash particles composed of reacted and unreacted sorbents. The products generated by these processes exhibit physical and chemical properties different from those of conventional coal ashes [12, 13, 14]. Most coal combustion by-products generated from both conventional and advanced combustion processes are non-toxic according to U.S. Environmental Protection Agency (EPA).

Applications of Coal-Combustion Products

Fly Ash

Fly ash can be used either as a raw material in the production of the cement clinker, interground with the clinker, or blended with the finished cement. Fly ash can be utilized as a major component of blended cements, exceeding 80% of total blended cement mixture [15]. It can be used as a replacement of up to 100% of sand in manufacturing flowable Controlled Low Strength Materials (CLSM) [16, 17, 18] suitable for foundation support and backfilling of excavations, bridge abutments, buildings, retaining walls, utility trenches, for filling abandoned tunnels, sewers, and other underground facilities, for embankments and grouts, and similar structural or non-structural applications. Fly ash can be used in manufacturing lightweight aggregates by using fired (sintered) and unfired (cold-bonded) processing methods [19, 20, 21].

Fly ash can be used in producing high-quality concrete pavements [22], structural concrete [23, 24], high-performance concrete [25, 26], precast/prestressed concrete products [27], roller-compacted concrete [28], and autoclaved cellular concrete (fly ash being used as a replacement of 30 to 100% of silica sand) [29]. Cenospheres derived from fly ash are an ideal filler material for manufacture of polymer matrix composites [30, 31].

Malhotra et al. [32] have advocated the use of large amounts of fly ash and other supplementary cementing materials in construction. They believe that the use of high-volume fly ash concrete should be made mandatory for the concrete industry in order to reduce CO_2 emissions.

Bottom Ash

The bottom ash consists of particles that appear to be to have numerous voids that could make the bottom ash lightweight, as well as particles that have a smooth glass-like appearance. Large size (greater than 6 mm) bottom ash can be used as coarse aggregate and small size bottom ash can be used as fine aggregate. Naik and his associates [33, 34] have reported that bottom ash can be used as lightweight aggregates. They also demonstrated the feasibility of using bottom ash in the manufacture of masonry products as a partial replacement of coarse as well as fine aggregates. Bottom ash used in CLSM slurry can also enhance insulating ability of the fill. Bakoshi et al. [35] demonstrated that compressive and tensile strengths of bottom ash concrete increases with an increase in the replacement ratio of fine aggregate. Freezing and thawing resistance of concrete using bottom ash was lower than that of ordinary concrete, whereas abrasion resistance was higher.

Boiler Slag

Boiler slag has been used as fine aggregate substitute in hot mix asphalt wearing surfaces and base courses. The most popular use of coal boiler slag is in architectural concrete as decorative aggregates [36]. Dehghanian and Soltani [37] have reported that addition of slag up to 7% improves the compressive strength of concrete significantly, and increases its diffusion resistance against corrosive-ions. They further reported that resistance of steel against pitting and uniform corrosion in the concrete containing slag was better than in the concrete without slag. Pavlenko and Chayka [38] presented the composition of fine-grained cement-less concrete on the basis of high-calcium fly ash slag sand, produced by burning brown coals. Concrete consisted of the by-products of thermal power plants and ferro-alloy works (silica fume). A compressive strength of

5 to 20 MPa was achieved, which is suitable for many types of load-bearing and non-load-bearing structures.

Clean-Coal Ash

Limited work has been reported concerning the use of clean-coal ash. Clean-coal ash can be used in construction of stabilized road base, as a raw material for manufacturing cement, in concrete and other cement-based materials, for manufacturing wallboards, and many other applications. Naik et al. [12] have reported that significant amount of clean-coal ash can be used in concrete as well as masonry products. Naik et al. [39, 40] have also established mixture proportions and production technologies for clean-coal ash in roadways and embankments, as well as CLSM as a replacement of sand and/or conventional fly ash.

Ghafoori and Mora [41] studied characteristics and long-term durability of laboratory-made compacted non-cement composites made with fluidized bed combustion (FBC) and pulverized coal combustion products. Based on their experimentation, they concluded that higher strength and expansion properties, and an improved performance in long-term durability, were attained with increases in fly ash to FBC ratio of the matrix. Furthermore inclusion of natural fine aggregate improved paste quality and properties of fly-ash-FBC compacted concretes.

PRODUCTION AND USE OF CCPs

1989-1995

Although 560 million tonnes (Mt) of fly ash, bottom ash, and boiler slag were produced in the world in 1989, only 90 Mt of this (16% of the total) was utilized [2]. Worldwide in 1992, based on available data, over 370 million tonnes (Mt) of fly ash and 90 Mt of bottom ash and boiler slag were produced; and, about 150 Mt (33%) were utilized [3]. 40 Mt were used in cement and concrete manufacture; 50 Mt in road construction and as filler on construction sites; 7 Mt in cellular concrete; 3 Mt in lightweight aggregate and bricks; over 40 Mt for filler for mines, quarries, or pits; and 3 Mt for soil amendment [3].

Production and use of fly ash, bottom ash, and boiler slag in selected countries in 1989-1995 are presented in Table 1.

Table 1. Production and Use of Fly Ash, Bottom Ash, and Boiler Slag in Selected Countries in 1989-1995 [3]

(Thousand tonnes)

	Year	Australia	Austria	Belgium	Bulgaria	Canada	China	Czecho-slovakia	Denmark	Finland	France
Production	1989	6,563	384	1,022	6,360	4,559	62,500	18,117	926	483	2,709
	1992	8,175	306	892		8,464	79,820	9,434	1,176	580	1,723
	1995	8,733					91,140		1,350		
Utilization											
Cement and Concrete Manufacture	1989	710	78	644	70	580	2,276	40	396	257	883
	1992	691	129	500		933	11,215	78	423	90	887
	1995	761					13,770		393	90	
Road Construction, Filler on Construction Sites	1989	30	18	121	10	705	8,300	973	359	155	105
	1992	127	5	55		5	10,417	59	488	127	525
	1995	719					18,510		798	350	
Cellular Concrete	1989					5		312	11		128
	1992					10		30	9		84
	1995								10		
Lightweight Aggregates, Bricks	1989			3	30		4,121	120			
	1992			7				170			
	1995										

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Table 1. Production and Use of Fly Ash, Bottom Ash, and Boiler Slag in Selected Countries in 1989-1995 [3] (cont'd)

(Thousand tonnes)

	Year	East Germany	West Germany	Germany	Greece	Hong Kong	Hungary	India	Israel	Italy	Japan	Nether-lands	Poland
Production	1989	19,057	12,310		6,246	1,124	4,817	40,000	410	1,380	3,800	855	29,500
	1992			20,040	7,630	912		38,889	523	1,010	4,131	862	14,010
	1995			16,842		635			750		4,725		
Utilization													
Cement and Concrete Manufacture	1989	705	2,130		757	163	148		250	1,020	1,250	345	338
	1992			3,760	800	341			347	242	1,520	599	521
	1995			3,519		594			628		2,850		
Road Construction, Filler on Construction Sites	1989	6,003	7,950			887	210			163	445	295	1,852
	1992			3,110		212			132		47	106	2,384
	1995			3,254		23					150		
Cellular Concrete	1989						239			27			920
	1992						239						530
	1995												
Lightweight Aggregates, Bricks	1989		320			74				31	122	120	345
	1992										149	133	
	1995			203							54		156

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Table 1. Production and Use of Fly Ash, Bottom Ash, and Boiler Slag in Selected Countries in 1989-1995 [3] (cont'd)

(Thousand tonnes)

	Year	Romania	Russia	Slovenia	South Africa	Spain	Taiwan	Turkey	UK	USA	USSR	Yugoslavia
Production	1989	29,000			28,000	8,695	1,361	17,115	15,500	65,234	125,000	13,337
	1992		62,000	1,084	30,000	8,875	1,505	13,866		59,999		
	1995		51,809	1,044			1,522			65,541		
Utilization												
Cement and Concrete Manufacture	1989	20			431	1,400	373		1,970	6,280	5,543	565
	1992		3,478	130	397	1,212	868	91		7,200		
	1995		4,370	3			899			8,089		
Road Construction, Filler on Construction Sites	1989	600			40	100			890	4,053	5,035	205
	1992		11,036		5,000	4,210	1			4,945		
	1995		9,868				1			3,645		
Cellular Concrete	1989	120							890		78	27
	1992		4,952									
	1995		4,386				44					
Lightweight Aggregates, Bricks	1989	5			21				522		844	65
	1992		771		174	24	49					
	1995		813				1					

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USA in 2001

CCPs production and use data for USA in 2001 are presented in Table 2.

Table 2. CCPs Production and Use in the U. S. in 2001 [6]

(Thousand tonnes, unless otherwise noted)

	Fly ash	Bottom ash	Boiler slag	Flue gas desulfur-ization material	Total	Use percent-age
Production	61,843	17,056	2,302	25,857	107,057	
Use						
Agriculture	11,221	708	0	443	12,372	11.6
Blasting grit and roofing granules	938	148	0	28	1,114	1.0
Cement clinker raw feed	730	7	0	0	736	0.7
Concrete and grout	2,914	1,053	14	172	4,153	3.9
Flowable fill	932	554	0	35	1,521	1.4
Mineral filler	669	103	0	0	772	0.7
Mining applications	97	7	11	1	117	0.1
Road base and subbase	0	775	17	0	791	0.7
Snow and ice control	0	36	1,353	0	1,389	1.3
Soil modification	744	108	0	127	979	0.9
Structural fills	0	0	0	5,651	5,651	5.3
Wallboard	1,307	63	0	43	1,412	1.3
Waste stabilization and solidification	19	20	0	104	143	0.1
Other	407	1,605	257	279	2,547	2.4
Total	19,976	5,186	1,651	6,884	33,697	31.5
Use percentage	32.3	30.4	71.7	26.6	31.5	

ECOBA in 2000

The membership of the European Coal Combustion Products Association (ECOBA) consists of companies and associations from the following 13 countries across Europe: Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Poland, Portugal, Spain, and the United Kingdom [4]. ECOBA members represent over 90% of the CCP production in Europe.

In the year 2000, the amount of CCPs produced by the ECOBA members were 60 Mt, which consisted of 66% fly ash, 18% FGD materials, 9.5% bottom ash, 4% boiler slag, 1.7% FBC ash, and 0.8% SDA product. Of the total CCPs produced, 54% was used in construction industry and underground mining, 35% in restoration of open mines, quarries, and pits, 6% as temporary stockpile, and, 5% was disposed [42]. Raw material shortages and favorable state regulations account for the high use rates of CCPs in Europe [5].

The physical and chemical requirements of fly ash per European Standard EN 450 are given in Table 3.

Production and use of CCPs by ECOBA members in 2000 are presented in Table 4. Detailed data for Poland for 2000 are presented in Tables 5 to 7.

Table 3. Physical and Chemical Properties of Fly Ash as per European Standard EN 450 [43]

Property	European Standard (EN 450 Fly Ash)
Minimum fineness (% retained on the 45 μm sieve)	≤ 40%, must be within ± 10% of declared mean value
Soundness	≤ 10 mm based on 50% fly ash + 50% CEM 1*
Sulfur present as SO_3	≤ 3%
Chloride	≤ 0.1%
Calcium Oxide (Expressed as free CaO)	≤ 1% or ≤ 2.5% if soundness satisfactory
Loss on Ignition	≤ 7%
Moisture Content	Dry
Water Requirement	(No Requirement)
Activity Index	≥ 75% @ 28 days and ≥ 85%@ 90 days. 25% fly ash + 75% CEM 1*

* CEM 1 = 42.5 MPa class.

Table 4. ECOBA Production and Use of CCPs in 2000 [4]

(Thousand tonnes, unless otherwise noted)

	Fly Ash	Bottom Ash	Boiler Slag	FBC-Ash	Other	SDA-Product	FGD-Gypsum	Total	% Use
Production	38,959	5,578	2,350	1,015	277	460	10,639	59,278	
Use									
Cement raw material	4,421	165		29				4,615	7.8
Blended cement	1,999			1				2,000	3.4
Concrete addition	5,973	0	156					6,129	10.3
Aerated concrete blocks	745	62						807	1.4
Non-aerated concrete blocks	343	970						1,313	2.2
Lightweight aggregate	14	52				2		68	0.1
Bricks + ceramics	68	5			10			83	0.1
Grouting	389		168					557	0.9
Asphalt filler	202							202	0.3
Subgrade stabilization	251	68						319	0.5
Pavement base course	414	218	1,216	38				1,886	3.2
General engineering fill	1,290	542		182	37	25		2,076	3.5
Structural fill	1,237	141						1,378	2.3
Soil amendment	175			58		78		311	0.5
Infill	577			357		244		1,178	2.0
Blasting grit		22	720					742	1.3
Plant nutrition	30		0			28		58	0.1
Set retarder for cement							793	793	1.3
Projection plaster							778	778	1.3
Plaster boards							4,499	4,499	7.6
Gypsum blocks							245	245	0.4
Self levelling floor screeds							1,329	1,329	2.2
Other uses	84	5	90	15	230	26	10	460	0.8
Beneficial Landfill. Land Reclamation. Restoration	17,032	2,619	0	182		33	733	20,599	34.7
Temporary stockpile	2,340	95	0	0		0	1,306	3,741	6.3
Total	37,584	4,964	2,350	862	277	436	9,693	56,166	94.8
Use percentage	96.5	89.0	100.0	84.9	100.0	94.8	91.1	94.8	

FBC: Fluidized Bed Combustion
SDA: Spray-Dryer Ash
FGD: Flue Gas Desulfurization

Table 5. CCPs Production in Poland in 2000 [44]

(Thousand tonnes)

	Fly Ash	Bottom Ash	Slag	FBC	FBC Slag	SDA	Fly Ash + SDA	FGD	Other	Total
CCPs from Hard Coal (Anthracite)	5,282,230	1,667,627	1,215,706	355,008	63,400	84,644	1,028,966	519,400	14,106	10,231,087
CCPs from Brown Coal (Lignite)	455,000	4,582,000	0	368,000	0	0	385,000	635,600	0	6,425,600
Total	5,737,230	6,249,627	1,215,706	723,008	63,400	84,644	1,413,966	1,155,000	14,106	16,656,687

Table 6. Hard Coal (Anthracite) CCPs* Production and Utilization in Poland in 2000 [44]

(Thousand tonnes)

	Fly Ash	Bottom Ash	Slag	FBC	FBC Slag	SDA	Fly Ash + SDA	FGD	Other	Total	% Use
Production	5,282,230	1,667,627	1,215,706	355,008	63,400	84,644	1,028,966	519,400	14,106	10,231,087	
Use											
Cement production	1,291,094	0	67,530	14,000	0	0	0	0	0	1,372,624	13
Building materials	785,006	9,180	127,335	0	23,200	0	7,666	0	0	952,387	9
Bricks and ceramics	217,580	128,889	157,768	0	0	0	2,000	0	0	506,237	5
Aggregate	94,500	6,200	0	0	0	0	0	0	0	100,700	1
Roads	0	60,466	166,825	0	1,400	0	3,000	0	0	231,691	2
Mining	1,781,408	83,366	297,461	261,008	30,000	55,510	1,016,300	0	0	3,525,053	34
Beneficial landfill, land reclamation	228,697	427,698	251,719	71,100	7,800	27,204	0	0	0	1,014,218	10
Other	178,024	118,201	130,356	0	0	0	0	0	0	426,581	4
Temporary stockpile	121,856	27,980	16,712	0	1,000	0	0	0	0	167,548	2
Total	4,698,165	861,980	1,215,706	346,108	63,400	82,714	1,028,966	0	0	8,297,039	81
% Use	89	52	100	97	100	98	100	0	0	81	

* Class F fly ash.

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Table 7. Brown Coal (Lignite) CCPs* Production and Utilization in Poland in 2000 [44]

(Thousand tonnes)

	Fly Ash	Bottom Ash	Slag	FBC	FBC Slag	SDA	Fly Ash + SDA	FGD	Other	Total	% Use
Production	455,000	4,582,000	0	368,000	0	0	385,000	635,600	0	6,425,600	
Use											
Cement production	0	0		0			0	0		0	0
Building materials	2,500	0		0			0	0		2,500	0
Bricks and ceramics	0	0		0			0	0		0	0
Aggregate	0	0		0			0	0		0	0
Roads	0	0		0			0	0		0	0
Mining	0	2,610,000		0			0	0		2,610,000	41
Beneficial landfill, land reclamation	452,500	0		368,000			385,000	0		1,205,500	19
Other	0	28,000		0			0	0		28,000	0
Temporary stockpile	0	0		0			0	0		0	0
Total	455,000	2,638,000		368,000			385,000	0		3,846,000	60
% Use	100	58		100			100	0		60	

* Class C fly ash.

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Other Countries in 2000

Production and use of CCPs in other countries in 2000 are presented in Table 8.

In 2000, Canada used about 23% (1.8 Mt) of 8 Mt of CCPs produced. India used about 13% (12.5 Mt) of CCPs produced, and the remainder was disposed in wet ponds. Japan used 84% of CCPs produced. The high disposal cost of CCPs in Japan ($100.00 per metric ton) probably accounts for this.

Table 8. Production and Use of CCPs in Other Countries in 2000 [5]

(Thousand tonnes, unless otherwise noted)

		Fly Ash	Bottom Ash	FGD-Gypsum	Total
Canada	Production	5,500	1,800	500	7,800
	Use	1,100	200	500	1,800
	% Use	20	11	100	23
India	Production	...	...	...	94,000
	Use	...	...	...	12,500
	% Use	...	...	...	13
Israel	Production	...	...	...	1,320
	Use	...	...	...	1,290
	% Use	...	...	...	98
Japan	Production	7,000	1,400	1,700	10,100
	Use	6,000	1,000	1,500	8,500
	% Use	86	71	88	84
Turkey	Production	...	...	...	20,000
	Use	...	...	...	...
	% Use	...	...	...	...

- ... Not available.
- Data not available on boiler slag, fluidized bed combustion (FBC) ash, and spray-dryer ash (SDA) product.

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