CADMIUM

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The cadmium market in 2000 continued in the same depressed state in which it has been for the past four years although there were some signs of improvement towards the end of the year. In spite of a continuing narrowing of the gap between production and consumption, especially for the 99.99% Cd battery grade material, cadmium prices did not improve in 2000, but remained at historically low levels. Consumption did increase and production did decrease from previous years, but these gains were partially offset by continued increases in the amounts of cadmium produced by nickel-cadmium battery recycling. Additional supply was also forthcoming from sales by the US Defense Logistics Agency (DLA). The most marked effect on the cadmium market in 2000 was the proposed ban on nickel-cadmium batteries in the European Union which is strongly opposed by industry and many governments, and which appears to have been proposed in the absence of an adequate risk assessment on these products and in possible violation of World Trade Organisation (WTO) agreements.

Production

Over the past ten years, primary cadmium production has slowly declined at a rate of approximately 0.8% per year. In the early 1990s, primary production levels were generally at 20,000 t/y and above. As the nickel-cadmium battery market matured and then levelled off, primary cadmium production levels declined to the 18,000 to 19,000 t/y range. In 2000, production of primary cadmium declined once again as zinc producers selected lower cadmium content concentrates or just did not fully process the cadmium contained in their zinc concentrates to refined cadmium metal. Because of extremely low prices for cadmium metal, land filling or storage of partially refined cadmium became an economically viable if not an environmentally positive alternative to full refining of the cadmium contained in zinc, lead and copper concentrates.

World primary production of refined cadmium metal, according to the World Bureau of Metal Statistics (WBMS), is summarised in Table I for 1990 through 2000.

World Primary Production of Refined Cadmium Metal (t)

Year	Production
1990	20,334
1991	21,268
1992	20,197
1993	19,497
1994	18,411
1995	19,478
1996	18,489
1997	19,836
1998	19,673
1999	18,735
2000	18,127

From a high primary production of almost 20,000 t in 1997, primary zinc producers have steadily reduced their cadmium production over the past four years in the face of a very flat cadmium market with virtually no price movement in all of 2000. On the other hand, increased secondary cadmium production from the recycling of nickel-cadmium batteries, along with sales of up to 544 t/y of cadmium from the DLA have steadily increased total cadmium supply (primary + secondary + DLA sales) so that the trend line for the 1990s is an increase in cadmium supply of about 0.8% per year. Thus, while primary cadmium production is slowing at

0.8% per year, total cadmium production is increasing at about 0.8% per year due to additional supply from recycling and DLA sales.

Secondary cadmium production will continue to grow in North America and Japan where voluntary industry NiCd battery collection and recycling programmes have received strong endorsements from governments. However, the situation in Europe is much more problematic where proposed bans on NiCd batteries are certain to discourage voluntary collection and recycling efforts. Efforts at mandatory collection and recycling in Europe thus far have produced only discouraging results, and it is likely that more mandates will not improve the situation. Thus, total cadmium supply is likely to continue to increase slowly, based mainly on the increases in secondary cadmium which will arise from North American and Japanese recycling.

Worldwide primary production of cadmium continues to arise predominantly from Asia, Europe and the Americas, with significant production still produced by Australia but very little from Africa. The relative primary cadmium production from these five geographic areas is summarised in Table II.

Geographic Summary of 2000 Primary Cadmium Production (t)		
Area	**Production**	**% of Total**
Asia	6,735	37.2
Americas	5,869	32.4
Europe	4,948	27.2
Australia	525	2.9
Africa	50	0.3
Total	***18,127***	***100.0***

The relative shares of cadmium produced in Asia, the Americas and Europe have shifted from previous patterns. In earlier years, Asian cadmium production, mostly from China and Japan, completely dominated the market. In 2000, however, Japanese production decreased somewhat from previous years. European production fell compared with previous years while cadmium output from the Americas rose. Thus, while the regulatory focus for cadmium is largely in Europe, the production and markets focus is clearly shifting away from Europe due to its punitive regulations against cadmium.

A similar type of pattern is established when the leading cadmium-producing countries are reviewed. The 12 leading primary cadmium-producing countries are summarised in Table III according to the World Bureau of Metal Statistics (WBMS).

Japan is the world's largest producer and consumer of primary cadmium with production ranging from 2,300 to 2,600 t/y from its six large producers (Dowa, Mitsubishi, Mitsui, Nippon, Sumitomo and Toho Zinc). Canada also continues to produce large quantities of cadmium from four producers (Falconbridge, Noranda, Hudson Bay and Cominco), over 2,000 t/y, which however are down somewhat from their highest levels in the mid 1990s. According to the WBMS statistics, cadmium production from the US also remains at moderately strong levels even though there are only three producers (Pasminco Zinc, INMETCO and Big River Zinc) still producing there. China is estimated to produce almost 2,000 t/y, much of which is for consumption in its own domestic NiCd battery production, but reliable figures are difficult to obtain. The only major producer in Belgium is Union Miniére which has steadily decreased its cadmium production over the past five years. Similarly, the figures reported for Germany are now only estimates, and it is somewhat doubtful that Metaleurop in Germany is producing over 1,000 t/y. The two large Mexican producers, Met-Mex Peñoles and Industrial Minera Mexico, continue to produce more than 1,200 t/y although interruptions in 1996 and 1999 curtailed production somewhat. Cadmium production from Kazakhstan has been volatile to say the least. It has been as high as 1,500 t in 1998 but last year sank to under 300 t

Russian production is estimated at around 750 t, but again reliable figures are difficult to obtain. Budelco BV in the Netherlands continues to produce 600 to 750 t/y, while Outokumpu in Finland normally produces 650 to 700 t/y. Finally, production from Pasminco Ltd in Australia is returning to more normal levels after reduced production in 1999.

Producers of Refined Cadmium Metal (t)					
Country	1996	1997	1998	1999	2000
Japan	2,357	2,373	2,342	2,586	2,439
Canada	2,433	2,260	2,090	2,091	2,091
US	1,525	2,059	1,878	1,878	1,878
China	1,567	1,982	1,982	1,983	1,983
Belgium	1,572	1,420	1,318	1,235	1,148
Germany	1,149	1,140	1,020	1,020	1,020
Mexico	784	1,223	1,275	787	1,310
Kazakhstan	567	745	1,463	1,061	257
Russia	716	750	750	750	750
Netherlands	603	718	739	731	628
Finland	648	650	520	700	680
Australia	639	632	585	462	525

It is much more difficult to establish the amounts of secondary or recycled cadmium. In the recycling of baghouse dusts from lead and copper smelters, the cadmium recovered subsequently enters primary cadmium production circuits at zinc refining operations and may or may not be included in the production statistics for primary cadmium metal. A considerable amount of the secondary cadmium produced today also comes from the recycling of nickel-cadmium batteries in the US, Japan and Europe. Recycling facilities to collect and recycle NiCd batteries exist in all three areas, and it is roughly estimated that over 1,600 Mt of cadmium were produced by NiCd battery recycling in 2000. Added to the 18,127 Mt of primary cadmium produced in 2000, the total amount of cadmium produced in 2000 is 19,727 t.

Another factor in the total cadmium supply situation since 1992 has been the disposal of cadmium by the US Defense Logistics Agency (DLA) from its excess cadmium stockpile. The original excess cadmium stockpile was 2,877 t, which DLA began to offer for sale on October 1, 1992. As of the end of its 1999/2000 fiscal year, which ran from October 1, 1999 to September 30, 2000, 1,983.6 t of DLA cadmium had been sold from its excess cadmium stockpile, leaving a remaining balance of 893.4 t. On May 7, 2001, the DLA sold an additional 105.2 t of excess cadmium from its stockpile, lowering the remaining level to 788.2 t. From the cadmium producers' viewpoint, the DLA sales are a negative market factor in that they have often placed more material on an already oversupplied market and have often been sold at prices substantially below prevailing market prices. From a cadmium consumer's or trader's viewpoint, the DLA sales offer opportunities to obtain material at low prices although the quality in some cases may be questionable. In 2000, the DLA sold 329.2 t of cadmium which, when combined with the 19,727 t of cadmium produced from primary and secondary sources noted above, yields a total cadmium supply in 2000 of 20,056 t. In addition, cadmium primary producer stocks were drawn down in 2000 by 762 t. Thus, total cadmium supply in 2000 is estimated roughly to be 20,818 t.

Consumption

Consumption statistics, as reported by the World Bureau of Metal Statistics (WBMS), generally refer to the conversion of cadmium metal into cadmium compounds such as cadmium oxide or cadmium sulphide, although some also may be included for direct metal use in alloy production and electroplating. Cadmium oxide produced from refined cadmium metal is normally either: incorporated into NiCd batteries for the negative electrode material; converted to cadmium sulphide pigments which are subsequently incorporated into plastics, glasses, enamels and ceramics; or used to produce organic cadmium compounds which are incorporated into PVC for heat and

ultraviolet light stabilisation. During 2000, WBMS made some major revisions in its previous cadmium consumption statistics which indicate that cadmium consumption is not decreasing as much as previously thought. World consumption of refined cadmium metal for the past ten years, according to the latest WBMS statistics, is summarised in Table IV.

It is not known the degree to which consumption of secondary cadmium has been factored into these consumption statistics or whether these represent consumption of primary cadmium production alone, which has been what WBMS normally reported in the past. If it is assumed that the above figures represent only primary cadmium production, then demand exceeded supply in 2000 for the first time in several years. Most primary cadmium producers today verify that this is indeed the case, that cadmium supply is tight, which is also confirmed by the first upward cadmium price movement in several years.

World Consumption of Refined Cadmium Metal (t)	
Year	**Consumption**
1990	18,960
1991	20,283
1992	17,870
1993	19,165
1994	18,149
1995	18,847
1996	17,726
1997	18,505
1998	18,104
1999	18,936
2000	20,666

The world's leading cadmium consuming countries are summarised in Table V. Good cadmium consumption statistics are not available for many countries, and often the WBMS statistics simply contain the same estimates as in previous years. However, the consumption levels for the world's largest NiCd battery producer, Japan, are considered quite accurate, as are some figures for other Western nations.

Consumption of cadmium in Japan is associated with the production of NiCd batteries, mainly by Sanyo and Panasonic (Matsushita). Consumption of cadmium in Belgium is also associated with NiCd batteries in that these statistics indicate the amounts of cadmium metal converted into cadmium oxide by companies such as Floridienne S.A. for subsequent use in the NiCd battery industry. US consumption reflects all cadmium applications, while most of the French consumption is directed for NiCd battery or cadmium pigment production. Thus, most of the cadmium consumed in individual countries reflects, directly or indirectly, usge in NiCd batteries.

Applications

Cadmium and cadmium compounds continue to be utilized in five major product areas which are NiCd batteries, pigments, coatings, stabilisers, and alloys and electronic compounds. The International Cadmium Association makes yearly estimates of the cadmium consumption patterns for these end-use categories which are summarised in Table VI.

Apparent Cadmium Consumption (t)					
Country	**1996**	**1997**	**1998**	**1999**	**2000**
Japan	6,527	7,247	5,795	6,550	6,909
Belgium	2,484	2,020	3,217	3,217	3,217
US	2,246	2,506	2,220	2,220	3,885
France	1,827	1,809	1,800	1,800	1,800
Russia	600	800	1,086	1,110	1,110
Germany	750	750	750	750	750
China	600	600	600	600	600
UK	618	631	626	631	607
India	446	446	446	446	446
S Korea	380	380	380	380	380

Estimated Worldwide Cadmium Consumption Patterns						
	% of Total Cadmium Consumption					
	1995	1996	1997	1998	1999	2000
Batteries	67	69	70	72	73	75
Pigments	14	13	13	13	13	12
Coatings	8	8	8	8	8	8
Stabilisers	9	8	7	6	5	4
Alloys and Compounds	2	2	2	1	1	1

The NiCd battery market is the only major cadmium market that continues to grow in spite of proposed European Community regulations. This market, at least from a cadmium consumption viewpoint, is made up of approximately 80% small consumer cells which are typically used in cordless power tools, cordless telephones and other communications devices, portable household appliances, emergency lighting, battery-powered toys and hobbies, and other portable electrical and electronic applications. The remaining 20% is consumed in the large industrial NiCd batteries used for railroad, aerospace, electric vehicle, standby power and telecommunications equipment applications. On a worldwide basis, both the portable and consumer NiCd battery markets continue to grow, although the consumer side has now flattened out in the highly advanced Western World countries where other battery technologies have taken over some market shares. In countries like China, however, NiCd battery production is growing very rapidly, and the Chinese NiCd battery producer, BYD, is now the world's fourth largest consumer NiCd battery producer behind Sanyo and Panasonic in Japan and SAFT in France and the US.

Future applications for cadmium include industrial NiCd batteries for electric and hybrid electric vehicles, telecommunications and remote area power systems. A 1998 estimate by SAFT America placed the potential cadmium market in NiCd batteries for telecommunications alone at 2,000 t/y. The latest figures for this market indicate that this potential is well on its way to realisation. As more advanced battery systems are developed and displace NiCd batteries from some of their current applications, it is expected that NiCd batteries will displace lower performance batteries such as lead acid and primary alkaline manganese chemistries in some of their applications. NiCd batteries are also especially promising for hybrid electric vehicles. Already approximately 10,000 of these NiCd-powered vehicles have been built in Europe, mainly by Peugeot and Renault in France, requiring over 500 t of cadmium.

Markets for cadmium pigments and coatings have stabilised over the past five years at roughly 20% of total consumption as it has been found to be very difficult to substitute for these products in those applications where their properties are required. For example, cadmium pigments cannot readily be replaced in plastics, glasses, enamels and ceramics that undergo high temperature or high pressure processing or exposure. Similarly, cadmium coatings cannot be replaced in applications that demand a good combination of high corrosion resistance and either low friction coefficient or low electrical resistivity. On the other hand, usge of organic cadmium compounds as stabilisers in polyvinyl chloride (PVC) continues to decline since the barium-cadmium stabilisers used in the past can now readily be substituted by barium-zinc, calcium-zinc or organo-tin stabilisers. Similarly, usage of cadmium in many brazing and soldering alloys has decreased as cadmium-free substitutes have been developed. Certain cadmium-containing alloys, however, such as the silver-cadmium oxide electrical contact alloys, have been very difficult to substitute, and will still remain a minor use for cadmium.

Included in the alloys and electronic compounds category are also the cadmium sulphide and cadmium telluride (CdTe) based electronic devices which are used in many

functions in today's electrical and electronic equipment. One of the most promising from the cadmium industry's perspective is the use of CdTe solar cells to convert sunlight into electricity and the use of NiCd batteries to store that electrical energy for remote area power systems (RAPS). One analysis suggested that the additional cadmium consumption from the CdTe/RAPS application could eventually be as high as 5,000 t/y, although current usage is only a fraction of that level. In addition, many other electronic cadmium compounds exhibit semiconducting properties which make them valuable for gates, switches, sensors, detectors and relays. These applications normally require high purity and therefore higher cost cadmium. The volume of cadmium consumed in these applications is small, but could increase in the future.

Future applications for cadmium will have to be recyclable. Today, batteries, coatings, alloys and CdTe solar cells are all recyclable. Both the NiCd battery industry and CdTe solar cell industry have undertaken product stewardship programmes to ensure that their cadmium-containing spent products and production wastes are collected and recycled. Recycling of coatings and alloys has generally not been justified economically in recent years in view of the low price of cadmium and/or the low cadmium content in the waste material being recycled. However, technologically it is possible to recycle both of these cadmium products, and both have been recycled in the past when economics were more favorable or when the recycling of very valuable metals was simultaneously involved such as in the recycling of silver-cadmium oxide electrical contact alloys. In addition, efforts are under way in the cadmium pigments industry to recycle cadmium pigmented engineering plastics, their major use.

From a public perception point of view, it is also necessary to emphasise that many of the applications for cadmium are a future solution for the environment and not a problem as they were in the past. Environmentally-positive applications such as electric vehicles, solar cells and long-lived, recyclable and rechargeable NiCd batteries to replace non-rechargeable and non-recyclable batteries are obvious environmental benefits to the continued use of cadmium products.

Prices

Throughout all of 2000, the *Metal Bulletin* published price for 99.95% Cd remained at US$0.17 to US$0.19/lb while that for 99.99% Cd stayed at US$0.20 to US$0.25/lb. These levels are the lowest ever recorded historically with data as far back as the 1940s, and are even lower if considered on an inflation-adjusted basis. Over the past 55 years, from roughly 1946 to 2001, the cadmium price has statistically averaged about US$2.00/lb. Thus, the cadmium metal prices suffered during the past five years have been particularly devastating to zinc producers who have not even been able to cover the cost of cadmium production at these price levels. However, as supply tightened late in 2000 and early in 2001, prices for 99.99% Cd material began to inch up again, and currently show at least some hint of recovery. The slightly improved price scenario has been brought about by reduced primary cadmium production offsetting increased secondary cadmium production and continued moderate demand in spite of regulatory proposals which discourage market growth.

Future Outlook

Today, cadmium supply and demand are in much better balance than a few years ago. The cadmium market today is somewhat tight, and cadmium prices are beginning to improve slightly from their historically low levels. The key to the future of the cadmium market will be whether such a balance can be maintained. As the amount of secondary cadmium produced from NiCd battery recycling continues to increase, the amount of primary cadmium produced as a by-product from primary zinc operations will have to correspondingly decrease. The only

viable way for such a development to occur is to increase the relative proportion of secondary zinc produced compared with primary zinc. The possibility of a future oversupply scenario could also be averted by increased cadmium consumption in new markets such as the industrial NiCd batteries for telecommunications applications, and continued growth for consumer NiCds in developing countries.

The NiCd battery market continues to be a strong and stable one for cadmium consumption in spite of the European Commission proposal to ban consumer NiCds in Europe. The pigments and coatings markets appear to have stabilised at about 20% of total consumption, but the stabilisers and alloys markets are rapidly declining and will probably be only about 1% of total consumption in five to ten years. Hybrid electric vehicles, telecommunications and remote area power systems are applications that hold considerable promise for future cadmium usage. However, the industry's ability to receive support from governments for cadmium product collection and recycling programmes is instrumental in realising any hope for the future. In North America and Japan, such support has been forthcoming. In Europe, a punitive approach designed to ban one substance after another, regardless of real risk to human health or the environment, is rampant with the result that already the production and consumption of cadmium and cadmium products is moving away from Europe towards other parts of the world, with the inevitable economic consequences for the European Union. The real pity is that the Environment Directorate of the European Commission has undertaken these regulations even before risk analyses have been completed demonstrating any need for such restrictions.