CADMIUM

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The cadmium market in 2001 showed modest signs of recovery as prices, especially for the 99.99% purity material used in NiCd batteries, increased significantly over the historic lows recorded in 2000. Primary cadmium production decreased slightly from 1999 and 2000 levels while secondary or recycled cadmium continued to increase. Cadmium consumption is becoming increasingly difficult to estimate because, while cadmium consumption from primary cadmium production is decreasing according to the World Bureau of Metal Statistics (WBMS), cadmium consumption in the NiCd battery industry from recycled or secondary cadmium is steadily increasing.

Figures from the NiCd battery industry suggest that consumption of cadmium in batteries is holding steady or, at worst, decreasing only slightly. Continued worldwide usage of cadmium in NiCd batteries is due to the strong growth of the Chinese NiCd battery industry and to the failure of the Environment Directorate of the European Commission to demonstrate that nickel-cadmium batteries constitute an unacceptable risk to human health and the environment which is necessary to justify their proposed ban on NiCd batteries by 2008.

Production

Figures from the (WBMS) indicate that annual primary cadmium production has been around 20,000 t since 1990. Although production dipped in the mid-1990s, output since 1997 has held steady in the 19,000 to 20,000 t/y level. These primary cadmium production levels have been maintained in spite of the fact that some zinc producers are no longer processing their cadmium to refined metal because of depressed prices, but are either land-filling or storing the impure sponge for future reclamation if prices improve.

World primary production of refined cadmium metal, according to the WBMS, is summarised in Table 1.

World Primary Production of Refined Cadmium Metal (t)

Year	Production
1991	21,268
1992	20,197
1993	19,497
1994	18,411
1995	19,478
1996	18,489
1997	20,133
1998	19,719
1999	19,993
2000	19,948
2001	19,357

The WBMS has revised its primary cadmium production statistics for 1997 through 2000 considerably from the figures shown last year. Thus, the decreasing trend that was shown last year for primary cadmium production has now become virtually flat over the past ten years. However, closer examination of the WBMS statistics indicate that its 2001 primary cadmium production estimates include significant increases for some countries which previously had little production, and high estimates for some countries where cadmium production cutbacks have been noted. These will be discussed in more detail below.

Worldwide primary production of cadmium continues to arise predominantly from Asia, Europe and the Americas, with significant output still produced by Australia. Cadmium production from the African nations, Algeria and Namibia, ceased as of 1998-1999. The relative primary cadmium production from the

four major geographic areas is summarised in Table 2.

Geographic Summary of 2001 Primary Cadmium Production (t)

Area	Production	% of Total
Asia	8,688	44.9
Americas	4,902	25.3
Europe	5,389	27.8
Australia	378	2.0
TOTAL	**19,357**	**100.0**

Asia continues to dominate world cadmium production with Japan, China, South Korea and Russia being its largest producers. Production from North and South America supplies about one third of total production with Canada, Mexico and the US being the largest producers. European production has diminished somewhat from previous years, probably because of the anti-cadmium regulations initiated by the European Commission. Belgium was still the largest cadmium producer in Europe in 2001 but its output has been decreasing steadily over the years and is expected to be reduced further in the future. Unexpected increases in cadmium production in 2001 were noted in Europe from Italy, Norway and Poland.

The 14 leading primary cadmium producing countries are summarised in Table 3.

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). Two of those producers (Mitsui and Toho Zinc) are also significant cadmium recyclers, but it is not known the extent to which secondary cadmium production may be included in their primary cadmium production figures. China has now become the world's second largest cadmium producer, with output nearly as large as that of the Japanese cadmium producers.

Most of the Chinese cadmium production is believed to be utilised for China's rapidly growing NiCd battery industry. In addition, South Korean cadmium production has increased by about 80% over the past five years, and South Korea is now the world's third largest cadmium producer. Russian production has also increased by about 17% in the past five years. The continued high production levels in Japan, coupled with increased production from China, South Korea, and Russia explain why Asia has come to dominate so completely the world's cadmium production.

Leading Producers of Refined Cadmium Metal, 1997 - 2001 (t)

Country	1997	1998	1999	2000	2001
Japan	2,373	2,342	2,586	2,439	2,467
China	1,982	2,125	2,154	2,368	2,368
South Korea	1,000	1,178	1,791	1,910	1,879
Mexico	1,223	1,275	1,275	1,268	1,436
Canada	2,260	2,090	1,911	2,024	1,429
US	2,080	1,240	1,190	1,890	1,400
Belgium	1,420	1,318	1,235	1,148	1,236
Germany	1,140	1,020	1,145	1,130	1,130
Russia	790	800	900	925	925
Finland	490	520	700	680	680
UK	465	440	547	503	485
Netherlands	718	739	731	628	455
Peru	359	405	426	480	473
Australia	632	585	462	525	378

Source: WBMS

In the Americas, Canada consistently produces about 2,000 t/y of cadmium from four producers (Falconbridge, Noranda, Hudson Bay and Teckcominco) although WBMS reports a significant drop in 2001 production from previous years. According to the WBMS statistics, cadmium production from the US also remains at moderately strong although somewhat inconsistent levels even though there are now only two producers

(Pasminco Zinc and INMETCO) still producing there. During 2001, Big River Zinc, the largest US cadmium producer, curtailed cadmium oxide production, which is probably the cause of the reduction from 1,890 t production in 2000 to 1,440 t in 2001. Mexican cadmium production increased during 2001 as a result of increased zinc production by the two large producers, Met-Mex Penoles and Industrial Minera Mexico, and Mexico is now listed as the world's fourth largest producer.

The only major producer in Belgium is Umicore (formerly Union Miniere) which has steadily decreased its cadmium production over the past five years, and which has recently announced that they would cease cadmium production in 2002. Cadmium production figures reported for Germany are only estimates, and it is doubtful that Metaleurop's production facility in Nordenham, Germany is producing over 1,000 t/y of cadmium. Pasminco Budel Zink BV in the Netherlands has decreased its cadmium production in recent years from over 700 t/y of cadmium in 1997 to about 450 t in 2001. Outokumpu in Finland normally produces 650 to 700 t/y of cadmium, while Britannia Zinc in the UK continues to produce about 500 t/y. Recently, it was announced that Britannia was also examining the possibility of recycling NiCd and other types of both primary and secondary batteries.

It is more difficult to establish the amounts of secondary or recycled cadmium. In the recycling of bag-house 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. Most of the secondary cadmium produced today comes from the recycling of nickel-cadmium batteries in the US, Japan and Europe. Estimates for the total amount of cadmium produced from NiCd battery recycling vary widely and some of the cadmium recycled, for example, at Toho Zinc and Mitsui Mining & Smelting in Japan, may be included in primary cadmium production figures as well. However, it appears that at least 1,800 t of cadmium were produced from NiCd battery recycling operations worldwide in 2001, and some have estimated the amount to be as high as 2,500 t.

Secondary cadmium production will continue to grow in North America, Europe and Japan where voluntary industry NiCd battery collection and recycling programmes have been developed. Large recyclers of NiCd batteries now include INMETCO in the US, SNAM in France, Accurec in Germany, SAFT AB in Sweden, and Toho Zinc, Mitsui Mining & Smelting, and Kansai Catalyst, all in Japan.

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 the DLA began to offer for sale on October 1, 1992. As of the end of its 2000/2001 Fiscal Year, which ran from October 1, 2000 through September 30, 2001, 2,098.8 t of DLA cadmium had been sold from its excess cadmium stockpile, leaving a balance of 778.2 t. An additional 143.8 t has been sold since October 1, 2001, leaving 634.4 t available for disposal as of April 15, 2002. The current approved rate of DLA excess cadmium disposals is 544.3 t/y. Thus, the DLA excess cadmium stockpile is expected to be exhausted in a few years and will no longer be a factor in the cadmium market.

From the cadmium producers' viewpoint, the DLA sales have been 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. Since the published prices for cadmium are normally established on the basis of reported spot sales which only constitute about 5% of total cadmium sales, the price at which DLA sales are made becomes a greatly exaggerated factor in determining the state of the cadmium market and published cadmium prices. Published

cadmium prices, as determined from the relatively small number of spot sales, including the DLA sales, then become the basis for the long-term contract prices. A relatively small amount of business thus produces a widespread effect upon the entire market. This was the case for DLA sales in FY 1999/2000 and FY 2000/2001 when large amounts of cadmium were sold at prices about 50% of published prices and acted to keep prices at depressed levels. The International Cadmium Association met with the DLA in January 2002 to express its concerns over this situation, and some constructive dialogue has emerged on how best to remedy the problems.

Consumption

Consumption statistics, as reported by the WBMS, generally refer to the conversion of primary 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
- utilised to produce organic cadmium compounds which are incorporated into PVC for heat and ultraviolet light stabilisation.

While WBMS made major revisions in its cadmium consumption statistics last year to show fairly steady consumption, this year's consumption figures exhibit a large drop from 2000 to 2001 that does not appear to be consistent with other market indicators. World consumption of refined primary cadmium metal for the past ten years, according to the latest WBMS statistics, is summarised in Table 4.

World Consumption of Refined Cadmium Metal (t)

Year	Consumption
1991	20,283
1992	17,870
1993	19,165
1994	18,149
1995	18,847
1996	17,726
1997	18,370
1998	18,054
1999	19,678
2000	19,254
2001	15,945

It is assumed that consumption of secondary cadmium has not been factored into these consumption statistics and that these figures represent consumption of primary cadmium production alone, which has been the normal WBMS practice in the past. Increasingly, toll conversion arrangements have been made between NiCd battery recyclers and NiCd battery producers to supply a good portion of their cadmium requirements. Therefore, if the 1,800 to 2,500 t of cadmium recycled in 2001 were indeed consumed by the NiCd battery producers, then total cadmium consumption would be 17,745 to 18,445 t, which appears somewhat more consistent with the production of NiCd batteries worldwide. The problem here is that it is not known the degree to which secondary cadmium may or may not be included in either production or consumption statistics. As secondary cadmium production increases, this factor has a greater and greater effect on the market. Thus, reliable secondary cadmium production and consumption numbers are absolutely necessary to obtain a clear picture of the cadmium market.

The world's leading cadmium consuming countries are summarised in Table 5. Good

cadmium consumption statistics are not available for many countries, and often the WBMS statistics simply retain 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.

World's Leading Consumers of Refined Cadmium Metal (t)

Country	1997	1998	1999	2000	2001
Japan	7,247	5,795	6,550	6,909	4,650
Belgium	2,020	3,217	4,085	3,559	3,559
US	2,506	2,030	1,850	2,010	1,440
France	1,809	1,800	1,800	1,800	1,800
Russia	840	1,136	1,260	857	345
Germany	750	750	750	750	750
China	600	600	600	600	600
UK	631	626	631	585	584
India	446	446	446	446	446
South Korea	380	380	380	380	380

Unfortunately, it appears as if the consumption statistics for Japan, Belgium, the US, Russia and the UK are the only ones that have changed from year to year. Consumption estimates for South Korea, India, China, Germany and France have remained virtually the same for the past six years. Most in the NiCd battery industry argue that consumption of cadmium in Japan has decreased somewhat, although probably not as much as the 33% indicated by WBMS, but that cadmium consumption in China has increased significantly in the past five years. Similarly, the precipitous drop in cadmium consumption in Russia in 2001 is not consistent with increased Russian cadmium production during the year and increased cadmium prices in 2001.

This year's WBMS figures also indicate a major revision to US cadmium consumption in 2000. Last year, US consumption for 2000 was listed as 3,885 t while this year's figures have reduced the estimate to 2,010 t. Thus, many uncertainties remain about cadmium consumption data by specific country. Much of the problem revolves around the method by which consumption is determined, eg conversion of refined metal to compounds (cadmium oxide and cadmium sulphide) or actual usage in end products, such as batteries, pigments, coatings, stabilisers, alloys and electronic compounds.

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 primary cadmium metal converted into cadmium oxide by companies such as Floridienne SA in Belgium for subsequent use in the NiCd battery industry around the world. US consumption reflects all cadmium applications, while most of the French consumption is directed towards NiCd battery or cadmium pigment production. Thus, most of the cadmium consumed in individual countries reflects, directly or indirectly, usage in NiCd batteries.

Applications

Cadmium and cadmium compounds continue to be utilised 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 6.

Estimated Worldwide Cadmium Consumption Patterns

Market Segment	Total Cadmium Consumption %				
	1997	1998	1999	2000	2001
Batteries	70	72	73	75	77
Pigments	13	13	13	12	12
Coatings	8	8	8	8	8
Stabilisers	7	6	5	4	2
Alloys & Compounds	2	1	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 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 probably the world's third largest consumer NiCd battery producer behind Sanyo 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. Approximately 10,000 NiCd-powered vehicles have already been built in Europe, mainly by Peugeot and Renault in France, requiring over 500 t of cadmium. European Commission Directive 2000/53, the End-of-Life Vehicle Directive, however, proposes to eliminate the use of NiCd batteries in electric vehicles by the end of 2005, even though many in the electric vehicle industry contend that other battery systems such as nickel-metal hydride (NiMH) and lithium-ion (Li-ion) are not economically suitable alternatives and won't be for some years.

Markets for cadmium pigments and coatings have stabilised in recent years at roughly 20 percent 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 resistance. On the other hand, usage 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 suitable 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, are exempted from European Commission cadmium product prohibitions, and will 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 that 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. However, another recently proposed European Commission Directive on Waste Electrical and Electronic Equipment (WEEE) has called for the complete elimination of cadmium in electronic equipment with very few exemptions. This European Commission proposal could produce future negative effects on the cadmium industry.

Future applications for cadmium must 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 favourable 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 underway 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 the problems 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 environmentally beneficial, and their continued use should be encouraged.

Prices

The Metal Bulletin published price for 99.95% Cd began 2001 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, the levels carried throughout most of 2000. However, in March 2001, the price for 99.99% Cd began to increase and reached a level of US$0.60 to US$0.65/lb during the period from August through October 2001. After October, 99.99% Cd price decreased slightly to the US$0.40 to US$0.50/lb. Prices for 99.95% Cd, however, improved only marginally during the year, going from lows of US$0.17 to US$0.19/lb at the beginning of the year to US$0.28 to US$0.33/lb by the end of 2001.

These large price differences clearly were a result of NiCd batteries, which generally require 99.99% Cd grade, dominating the market. The improved cadmium prices during 2001 were largely a result of continued demand in the NiCd battery sector, and some fears that low zinc prices would lead to cutbacks in zinc production and thus curtailed co-product cadmium production. Such fears did not, however, materialise, as cadmium supply, both from primary and secondary sources, remained at reasonably high levels.

Outlook

The cadmium industry is very much in a state of flux. While total production, including primary co-product production from zinc refining and recycling of NiCd batteries, is increasing, it is difficult to determine whether or not consumption is keeping pace with production. Proposed regulations by the European Commission have been, and will continue to be, very destructive of the cadmium market. The efforts of a few

extreme European Union (EU) nations, such as Sweden, Netherlands and Denmark, have been able virtually to forbid the use of cadmium in a wide range of products in the EU in spite of the fact that risk assessments on these cadmium products have yet to demonstrate any unacceptable risk. It appears that these countries would prefer to ban without a scientific basis for doing so rather than reducing any environmental and human health risk through collection and recycling programmes.

If the relative amounts of secondary or recycled cadmium continue to increase and the relative amounts of primary cadmium continue to decrease, then a balance between supply and demand can be struck. However, such a balance depends on continued consumption in the NiCd markets, growth in Third World markets, and continued stability in the pigments and coatings markets. Hybrid electric vehicles, telecommunications and remote area power systems are all possibilities for future cadmium market growth areas, but they will not be realised unless the European Commission's total ban approach is modified, collection and recycling programs are utilised to reduce risk rather than bans, and real risk assessments are performed to determine the need, if any, for cadmium product bans. While the effects are most strongly felt in Europe and cadmium consumption and production has decreased in recent years in Europe, there is danger that they may spread to other parts of the world as well.