CADMIUM

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The cadmium market continued to improve in 2002. Prices rose in the face of steady or increasing demand, especially from the Chinese nickel-cadmium (NiCd) battery industry, decreasing primary production and decreasing stocks, which were only partially offset by increases in secondary production from the recycling of NiCd batteries. Primary cadmium production is decreasing because of cutbacks in primary zinc in response to an oversupply of zinc in the world market, and secondary cadmium production is increasing owing to voluntary industry programmes for collecting and recycling NiCd batteries in Europe, Japan and North America.

Against these positive factors for the cadmium market in 2002, the continuing initiatives of the Environment Directorate of the European Commission to ban or restrict NiCd batteries in the EU must be considered. These initiatives have been delayed for about six years now and there is still strong resistance to them from both within and outside Europe, and from industry around the world. At present, targeted risk assessments on cadmium/cadmium oxide and NiCd batteries, as well as extended impact assessments, are being performed on the proposed NiCd battery bans to determine whether they are scientifically necessary or justified.

Production

Figures from the World Bureau of Metal Statistics (WBMS) indicate that primary cadmium metal production has been declining slowly, from more than 20,000 t in 1992 to about 16,600 t in 2002. The decrease has been most marked since 1997. In some cases, the decline has been a result of reduced zinc production. In other cases, some zinc producers have deliberately chosen not to process their cadmium through to a final product because of extremely depressed cadmium prices during the 1996-2001 time period. There are also those who have chosen to process only low-cadmium zinc concentrate, again because of the depressed cadmium market. In 2002, however, the main reason for the decrease in primary cadmium output was the cessation of cadmium production by Umicore SA in Belgium early in the year. In the past, Umicore (previously known as Union Minière SA), produced as much as 1,700 t/y of cadmium and was probably the world’s largest single cadmium producer.

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

Worldwide, primary cadmium production continues to originate predominantly from Asia, the Americas and Europe. Australian production has declined significantly from its levels in the early 1990s, and African production today is essentially non-existent. The interesting trend is that, while primary production from the Americas and Europe has been declining, cadmium output from Asia has increased dramatically. The trends in geographical primary cadmium metal production are summarised in Table 2.

Amongst the Asian nations, China, Japan, South Korea and Russia are the leading producers. In the Americas, Canada, Mexico and the US are now the most significant producers, whilst in Europe, the Netherlands, Germany and Scandinavia are today's largest cadmium-producing regions. Production from the leading primary cadmium metal-producing countries is shown in Table 3.

In Japan, the leading cadmium producers are Mitsui Mining & Smelting and Toho Zinc, both of whom are also involved in the recycling of NiCd batteries. The leading Chinese cadmium producers include Zhuzhou, Huludao, Shaoguan and Baiyin, whilst the main producer in South Korea is Korea Zinc. The principal Mexican producers are Industrial Minera Mexico and Met-Mex Penoles. The four Canadian producers include Noranda, Falconbridge, Hudson Bay and Teck Cominco. In the US, cadmium is produced by Pasminco Zinc US and Inmetco, a recycler of NiCd batteries.

As noted above, the single largest factor causing decreased primary cadmium metal production in 2002 was the cessation of cadmium production by Umicore in Belgium. However, other cadmium production has also shut down, is scheduled to close shortly or is in the process of being sold for various reasons. Asturiana de Zinc in Spain had stopped producing cadmium several years ago, but has now acquired the German zinc smelter Nordenham from Metaleurop, and it is unclear whether or not Nordenham will continue to produce cadmium. Other zinc plants with cadmium production which are threatened with shutdown include MIM's Britannia Zinc in the UK and Glencore's Porto Vesme refinery in Italy. In addition, there have been reports of cutbacks in Chinese zinc production, and thus cadmium production, because of the world oversupply of zinc. Unfortunately, the zinc industry will not increase zinc production simply because the cadmium market is improving. Cadmium production must follow zinc production and not vice-versa.

However, even though primary cadmium supply is decreasing, secondary cadmium supply has been increasing steadily over the past few years. There are three major industry collection and recycling programmes in the world – the Rechargeable Battery Recycling Corp. (RBRC) programme in the US and Canada, the Battery Association of Japan (BAJ) programme in Japan, and the CollectNiCad (CNC) programme in Europe. All three programmes have exhibited consistent gains in total tonnages of NiCd batteries collected and recycled since their inception, and all of the recyclers associated with these programmes have realised increased cadmium output year-on-year. These recyclers include Inmetco in the US, SAFT in Sweden, SNAM in France, Accurec in Germany, and Mitsui Mining & Smelting, Toho Zinc, Kansai Catalyst, Nippon Recycling Centre and Cobar Ltd in Japan. In total, these recyclers are estimated to produce about 3,000 t/y of cadmium from the recycling of spent NiCd batteries.

The third factor in establishing total available world cadmium supply has been the material available from stockpiles. The US Defense Logistics Agency (DLA) at one time held a cadmium stockpile of approximately 2,800 t, from which it has sold into the market over the past ten years, generally at a rate of 540 t/y or less. The DLA stockpile is now virtually depleted, however, and the remaining balance of less than 20 t is expected to be sold during the first half of 2003. Summarised in Table 4 are the US DLA cadmium disposals since it began offering material on October 1, 1992.

Thus, the average yearly cadmium disposal from the DLA has been about 250 t/y. In contrast, primary cadmium metal production has ranged from 16,000 t to 20,000 t annually over the past ten years, and secondary cadmium production has ranged from 1,000-3,000 t/y. In 2002, total cadmium supply consisted of 16,623 t of primary production, roughly 3,000 t of secondary production and 247 t from the DLA stockpile, for a total supply of approximately 19,800 t. Thus, roughly 84% of total cadmium supply came from primary sources, 15% from secondary sources and 1% from the DLA stockpile.

What is considerably less certain is the amount of material supplied to the market from other existing stockpiles, or the amount of cadmium remaining in stockpiles around the world. Because of the extremely depressed cadmium market from 1996 until 2001, many producers curtailed production and may have simply stockpiled impure cadmium sponge against expectations of future improvements in price. WBMS statistics for producer stocks show that they have decreased from levels as high as about 4,500 t in the mid-1990s to about 2,000 t at the end of 2002.

Kazakh production in 2000 and 2001, for example, was severely curtailed, but it is rumoured that much of that material was simply stockpiled and will now be refined to high-purity form since cadmium prices have improved. Big River Zinc in the US was formerly a significant producer of cadmium oxide, but no longer produces this material. Is the cadmium it removes from its zinc concentrate being stockpiled, sold or simply disposed of as a hazardous waste? Similar rumours have surfaced concerning stockpiles of cadmium in Russia and Eastern Europe, and the possible presence of these stockpiles may help explain why the cadmium market has not taken off more rapidly than it has, considering the seemingly significant imbalance between supply and demand.

Consumption

Apparent cadmium consumption is often very difficult to establish accurately. The figures generally reported are those for conversion of cadmium metal into cadmium oxide or cadmium sulphide, the direct use of cadmium metal for electroplating and coatings, and usage for production of cadmium-containing alloys and specialised chemical salts. The problem here is that cadmium oxide is often used as the starting material for other cadmium products, and that cadmium oxide is the primary material used in NiCd batteries. Thus, there is always the danger that cadmium consumption figures may include double counting, for instance, once in the conversion of metal to oxide and once again in the use of the oxide in NiCd batteries.

Also, it must be noted that the consumption figures presented by WBMS, which are still the most consistent and reliable figures available, refer to consumption of primary cadmium and do not take into account consumption of secondary cadmium. It is well known that many NiCd battery manufacturers have arrangements with NiCd battery recyclers to supply a significant portion of their requirements, and indeed that the industrial NiCd battery manufacturer, SAFT, even has its own worldwide collection and recycling system and a recycling plant in Sweden.

The world's apparent consumption of primary cadmium metal, according to WBMS, is summarised in Table 5.

These apparent consumption figures represent significant revisions from last year for the years 1998-2001, and presumably represent a much more detailed awareness of the extraordinary increases in Chinese cadmium consumption which have occurred in the past few years. Comparison of the consumption data in Table 5 with the total supply information discussed in the previous section indicates that apparent demand exceeds estimated supply by about 1,000 t to 2,000 t. As previously discussed, some of this shortfall may be supplied by existing stockpiles, but the general consensus is that these stockpiles are now rapidly being depleted.

The world's leading cadmium-consuming countries, according to WBMS, are summarised in Table 6. Although the cadmium consumption statistics for some countries such as Japan are believed to be quite accurate, those for other nations are only estimates, and many have remained unchanged for years. For example, it has only been recently that the enormous cadmium consumption occurring in China has been recognised and more accurate consumption figures obtained. Also, it must be kept in mind that the consumption figures for Belgium reflect simply the conversion of cadmium metal into cadmium oxide as there are virtually no other cadmium-consuming industries in Belgium of any magnitude.

China has now replaced Japan as the world's largest consumer of cadmium, and virtually all of that consumption is utilised in the production of NiCd batteries by manufacturers such as BYD and GP. Japan, however, still consumes a very large portion of the world's cadmium.

Two of the world's leading producers of small portable batteries, Sanyo and Matsushita/Panasonic now also have manufacturing facilities in both Japan and China. Belgium converts cadmium metal into cadmium oxide, most of which is shipped either to China or Japan for the production of NiCd batteries. France, because of SAFT's extensive NiCd production facilities there, is the fourth-largest cadmium consumer in the world. Thus, the top four cadmium-consuming countries in the world are all closely associated with strong NiCd battery manufacturing or raw material production operations.

Applications

Cadmium and cadmium compounds are utilised in five major product areas which include NiCd batteries, pigments, stabilisers, coatings, and alloys, electronic compounds and miscellaneous applications. Definitive figures are not maintained for these application areas, although the International Cadmium Association makes yearly estimates of cadmium consumption patterns for end-use categories which are summarised in Table 7.

The NiCd battery share of the cadmium market has continued to grow, and the stabilisers and alloys categories have continued to decrease. Cadmium sulphide- based pigments for use in plastics, glasses, ceramics and artists' colours, as well as cadmium coatings for iron and steel, aluminum and titanium, have maintained steady usage throughout the world in spite of partial restrictions in the European Union. Cadmium-based products have been found to be irreplaceable in many pigment and coatings applications, and even the EC Directive 91/338/EEC on cadmium product restrictions grants exemptions for most of these irreplaceable applications. Restrictions do not exist on cadmium products outside the EU.

Cadmium-based stabilisers such as the barium sulphate-cadmium carboxylates (cadmium laurate or cadmium stearate) have been used extensively in the past to provide ultraviolet light and weathering resistance to polyvinylchloride (PVC). However, it has been found that other cadmium-free compounds, such as calcium-zinc, barium-zinc and organo-tin stabilizers, can be utilised equally well although they do not always perform as well and are often not as cost-effective. Nevertheless, the ready availability of substitutes for many PVC applications has led to a general decrease in the usage of cadmium-barium stabilisers for PVC.

Similarly, there have been many different types of cadmium-containing alloys used in the past for brazing and soldering alloys that are now being replaced by cadmium-free compositions with equal performance. There remain, however, several cadmium-containing alloys that have been found to be very difficult to replace. These include the silver-cadmium oxide electrical contact alloys used in switches and other applications where high electrical conductivity must be maintained along with arcing and electrical erosion resistance. Other unique alloys are the high-performance copper-cadmium alloys. These are employed in heat-conductivity or electrical-conductivity applications where improved strength is imparted by the cadmium addition but virtually no loss in either heat or electrical conductivity.

Those cadmium applications which continue to grow are all centered around the NiCd battery which has proven to be a very reliable, cost-effective battery for many applications in spite of the development of many other advanced battery systems and proposals for use restrictions in the EU. This market, at least from a cadmium consumption viewpoint, is made up of approximately 80% small portable cells, used typically 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 more technically advanced Western countries where other battery technologies have captured some market shares. In countries such as China, however, NiCd battery production is growing very rapidly, and the Chinese NiCd battery producer, BYD, is now probably the world's second-largest portable NiCd battery producer behind Sanyo in Japan. A very detailed study of cadmium consumption in NiCd batteries in Europe for the year 2000 was performed by CollectNiCad, and indicates the great importance of the portable power-tool industry to the NiCd battery and cadmium industries. The results of this study are summarised in Table 8.

Thus, cordless power tools accounted for about 40% of the cadmium consumption in NiCd batteries in Europe for the year 2000, and emergency lighting and security applications accounted for about 21%. The cordless power tool industry is expected to continue to grow strongly, and, even though all manufacturers have examined other battery chemistries as potential substitutes, no other battery has been found to be as cost-effective and suitable for this application as the NiCd battery.

Future applications for NiCd batteries include electric and hybrid electric vehicles, telecommunications, and remote area power systems. A 1998 estimate by SAFT America placed the potential cadmium market for NiCd batteries in telecommunications alone at 2,000 t/y, and that market is slowly but steadily developing. 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 the lead acid and primary alkaline manganese chemistries in some of their applications. NiCd batteries are also especially promising for hybrid electric vehicles. Recently, Toyota abandoned its production of a nickel-metal hydride (NiMH)-powered hybrid electric vehicle based mainly on cost and performance factors, but NiCd-powered electric vehicles produced by Peugeot and Renault in France continue to be produced and sold in Europe. However, an EC Directive, the End-of-Life Vehicle Directive, 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 NiMH and lithium-ion (Li-ion) are not economically suitable alternatives and won't be for some years.

Included in the alloys and electronic compounds category are 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 semi-conducting 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.

Another new EC Directive on the Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS) has called for the complete elimination of cadmium in electronic equipment with only a few exemptions. This Directive could produce future negative effects on the cadmium industry unless additional exemptions are granted for critical applications where other materials are inadequate or not cost-effective.

Future applications for cadmium should be recyclable to the greatest extent possible. 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, it is now technologically 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 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 sustainable, and need not be viewed as detrimental to human health and the environment as they have been 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, not banned.

Prices

At the end of 2000, published *Metal Bulletin* average prices for both 99.95% and 99.99% grade cadmium metal were at close to their lowest historical levels, about US$0.20/lb. In March and April 2001, the price for high purity 99.99 grade cadmium jumped up to about US$0.50/lb, but the average price for 99.95 grade remained at US$0.30/lb for most of 2001. Later in 2001, prices for 99.99 NiCd battery-grade material increased again, to above US$0.60/lb, but then fell back down to the US$0.30/lb level for the first half of 2002. Beginning in August and September 2002, prices, first for 99.99 grade and then for 99.95 grade, began to increase sharply. By the end of 2002, the price range for 99.99 grade material stood at US$0.70-US$0.85/lb, and that for 99.95 grade at US$0.60-US$0.70/lb. Although these prices were certainly an improvement from the all-time historical lows of US$0.20/lb seen in 2000, they are still considerably below the average cadmium price over the past 50 years of approximately US$2.00/lb and even below the level of US$1.00/lb which many producers consider as roughly the production cost for cadmium.

Thus, even though the cadmium market and cadmium prices appear to be improving, they have been depressed so low and for so long that considerable and sustained improvements will be necessary to restore industry health. The current supply-demand imbalance will tend to improve cadmium prices and perhaps encourage those producers who had abandoned cadmium production to resume it, but such a resumption may not be possible in all cases.

Increased recycling of NiCd batteries will have to be utilised to help address any shortfall in supply in the future, as well as manage any risks present from the disposal of spent NiCd batteries.

Outlook

The cadmium market today is in a great state of flux. Primary cadmium supply is decreasing, but secondary cadmium supply is increasing. Excess cadmium stocks appear to have diminished or been depleted. As a result, cadmium prices have moved back up towards the breakeven production price of US$1.00/lb, but are still well below the historical price average of US$2.00/lb over the past 50 years. Cadmium applications are increasingly dominated by the nickel-cadmium battery, particularly the small portable consumer cells used in power tools, emergency lighting and security, household appliances, cordless telephones and other communications devices. A modest but steady use continues in cadmium pigments and coatings for certain critical applications where viable substitutes have not been established. Cadmium stabilisers and alloys are being replaced and eventually will disappear, but a small usage will probably develop for cadmium-based electronic compounds in solar cells and other electronic applications.

The continued strength of the NiCd battery market has resulted from the strength of Chinese NiCd battery production. This is due in large part, to China’s advantageous costs for labour, production and overheads. Although this increased Chinese production represents some shift of Japanese production to Chinese sites, it is also due to considerable new consumption within China and to China’s growing exports of cadmium. In the future, it is also possible that strong growth may occur in other Third World markets such as India, Russia and Brazil, although perhaps not as strong or as rapid as the Chinese explosion of the past five years.

The positive factors for the NiCd battery and cadmium markets must be tempered with the concerns surrounding cadmium in regard to health and environmental issues, and the steps that the EC Environment Directorate has taken, along with certain Nordic countries, to restrict the use of NiCd batteries. It is believed that the risk has been greatly exaggerated and that the final risk assessments developed by the EC will show that the levels of risk associated with the manufacture, use and disposal of these batteries are not unacceptable.

Any risks shown to be present with regard to NiCd batteries can largely be mitigated by the development of NiCd battery collection and recycling programmes such as those established by the BAJ in Japan, RBRC in the US and Canada, and CollectNiCad (CNC) in Europe. Eventually, these programmes must be worldwide, and already several countries in Asia and South America have explored the possibilities of establishing labelling, collection and recycling programmes for NiCd batteries. Indeed, many jurisdictions are looking at the collection and recycling of all battery chemistries, recognising that recycling is probably a far more important environmental impact factor than the actual battery chemistry.

Cadmium will continue to be produced as a by-product as long as zinc, lead and copper are produced. The real questions are whether primary producers will elect to curtail cadmium production because of environmental regulations and poor economics, or whether cadmium will continue to be refined and utilised as a valuable by-product and then recycled so as to minimise any human health or environmental impact. Industry would prefer the latter, but at this transition point must also examine all options.

Table 1
World Primary Production of Refined Cadmium Metal.

Year	Production (t)
1992	20,197
1993	19,497
1994	18,411
1995	19,478
1996	18,489
1997	20,153
1998	19,312
1999	19,539
2000	19,363
2001	17,747
2002	16,623

Table 2.
Geographical Trends in Primary Cadmium Production % Share by Region.

Year	Asia	Americas	Europe	Australia
1995	36.0	27.4	31.5	4.6
1996	37.2	29.7	29.2	3.5
1997	35.5	29.7	31.3	3.2
1998	43.9	26.8	26.0	3.0
1999	46.1	25.2	26.1	2.3
2000	43.5	29.4	24.1	2.7
2001	47.6	23.5	26.8	2.1
2002	46.6	25.9	25.2	2.3

Table 3.
Leading Producers of Refined Cadmium Metal.
Refined Cadmium Metal Production (t)

Country	1998	1999	2000	2001	2002
Japan	2,342	2,586	2,439	2,467	2,589
China	2,125	2,154	2,368	2,368	2,368
South Korea	1,382	1,995	2,114	2,083	2,041
Mexico	1,275	1,275	1,268	1,421	1,464
Canada	2,090	1,911	1,941	1,429	1,429
Russia	800	900	925	925	925
US	1,240	1,190	1,890	680	680
Kazakhstan	1,463	1,061	257	170	615
Netherlands	739	731	628	455	473
Germany	617	703	458	539	394
Belgium	1,318	1,235	1,148	1,236	200

Table 4.
US Defense Logistics Agency Cadmium Disposals (t)

Fiscal year*	Authorised limit	Amount sold
1992 / 1993	227.3	148.9
1993 / 1994	340.9	339.8
1994 / 1995	340.9	360.9
1995 / 1996	443.2	00.0
1996 / 1997	544.3	141.7
1997 / 1998	544.3	118.8
1998 / 1999	544.3	544.3
1999 / 2000	544.3	329.2
2000 / 2001	544.3	115.2
2001 / 2002	544.3	436.6
2002 / 2003	544.3	247.3
Total		**2,782.7**

*DLA fiscal year is October 1, through following September 30.

Table 5.
Worldwide Apparent Consumption of Cadmium Metal.

Year	t
1991	20,283
1992	17,870
1993	19,165
1994	18,149
1995	18,847
1996	17,726
1997	18,370
1998	19,623
1999	21,141
2000	22,737
2001	20,077
2002	21,053

Table 6.
World's Leading Consumers of Refined Cadmium Metal.
Apparent Cadmium Consumption (t)

Country	1998	1999	2000	2001	2002
China	2,409	2,856	4,854	5,268	6,356
Japan	5,795	5,851	6,810	4,650	5,589
Belgium	3,217	4,065	3,559	4,426	3,559
France	1,800	1,800	1,800	1,800	1,800
US	2,030	1,850	2,010	679	679
UK	626	631	585	584	587
India	446	446	446	446	446
Germany	680	658	412	593	426
Russia	1,136	1,260	816	308	345
South Korea	380	380	360	200	123

Table 7
Estimated Worldwide Cadmium Consumption Patterns.
Market Segment % of Total Cadmium Consumption.

	1995	1996	1997	1998	1999	2000	2001	2002
Batteries	67	69	70	72	73	75	77	78
Pigments	14	13	13	13	13	12	12	12
Coatings	8	8	8	8	8	8	8	8
Stabilizers	9	8	7	6	5	4	2	1.5
Alloys and Compounds	2	2	2	1	1	1	<1	0.5

Table 8.
Cadmium Consumption in NiCd Batteries in Europe in 2000.

Application	Consumption (t)
Cordless Power Tools	810
Emergency Lighting and Security	433
Military, Space and Computers	135
Cordless Shavers and Tooth Brushes	108
Electric Vehicles	105
Stationary and Stand-By Power	95
Cordless Telephones	94
Cordless Vacuum Cleaners	80
Railway and Metro Applications	70
Individual Cells	54
Walkman and Diskman Devices	27
Aircraft Starting and Emergency Power	11.5
Camcorders	8
Space Satellite Applications	0.1
Total	**2,030.6**