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(Part- II Metals and Alloys)

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CADMIUM

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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3 Cadmium

Cadmium is a soft, bluish-white metal of low melting point which is present generally in zinc ore deposits as greenockite (CdS). The principal source of cadmium is zinc ore, sphalerite. Other sulphides and sulphosalts may also carry small amounts of the metal.

In India, cadmium is recovered as a by-product during zinc smelting and refining. The concentration of cadmium in sphalerite, the principal ore of zinc, ranges from 0.03 to 9.0 wt%. In zinc concentrate at Rampura Agucha, the concentration of cadmium is 0.18% while in lead concentrate, it is 150 ppm. There are no separate resources of cadmium.

INDUSTRY

The total installed capacity for recovering cadmium was 913 tonnes of which HZL accounted for 833 tpy capacity. Binani Zinc Ltd (Edayar Zinc Ltd) reported the remaining 80 tpy capacity (Table-1). HZL produces cadmium of high quality in its zinc smelters which is casted in the form of pencils weighing from 250 g to 500 g. The purity is 99.95% Cd (max.) at Debari; 99.97% Cd (max.) at Vizag and 99.99% Cd (min.) at Chanderiya plants. HZL has plans to conduct R&D for production of high purity cadmium. High purity cadmium is typically used for nuclear shielding applications.

Table – 1 : Installed Capacity for Recovery of Cadmium

Unit	Location	Installed capacity (tpy)
Total		**913**
1. HZL, Debari Zinc Smelter	Debari, Distt. Udaipur, Rajasthan.	250
2. HZL,* Vizag Zinc Smelter	Visakhapatnam, Andhra Pradesh.	115
3. HZL, Chanderiya Lead-Zinc Smelter	Chanderiya, Distt. Chittorgarh, Rajasthan.	468
4. Binani Zinc Ltd** (Edayar Zinc Ltd)	Binanipuram, Distt. Ernakulam, Kerala.	80

** Operation suspended since 2002*
*** Operation suspended since April-2014*

USES

Cadmium is used to control the fissionable elements in nuclear reactors. Along with nickel, it is used in electrical storage/rechargeable batteries. Cadmium-based bearing alloys are used in high-speed internal combustion engines. Copper-cadmium alloys possess high strength, high conductivity and high resistance to abrasion, and therefore, the alloys are used in electric transmission wires. The main use of cadmium is in electroplating where it can be applied as a very thin coating to protect iron, steel, copper alloys and other metals and alloys from corrosion. Cadmium sulphide forms brilliant golden yellow, orange-red or reddish brown pigments used in paint, enamel, soap, rubber, glass and ceramic glazes. Some cadmium salts are also used in photographic films and in lithography. Cadmium coated products are preferred for a wide range of critical and safety-related applications in the aerospace, electrical, defence, mining, nuclear fission, television and offshore industries. Cadmium plating is used mainly in the aviation and aerospace industries to protect fastners exposed to hostile environments.

PRODUCTION & PRICES

Production of cadmium is reported as a by-product of zinc smelting and is 47 tonnes in 2017-18 as compared to 35 tonnes in the previous year. The entire production in 2017-18 was reported from the state of Rajasthan (Tables-2 and 3). The foreign market prices of cadmium are furnished in the General Review on "Prices".

Table – 2 : Production of Cadmium 2015-16 to 2017-18 (By State)

(Quantity in tonnes; Value in `'000)

State	2015-16		2016-17		2017-18 (P)	
	Qty	Value	Qty	Value	Qty	Value
India	-	-	**35**	**4463**	**47**	**5685**
Rajasthan	-	-	35	4463	47	5685

Table – 3 : Production of Cadmium, 2016-17 and 2017-18
(By Sector/State/District)

(Quantity in tonnes; Value in `'000)

State/District	Smelter	2016-17		2017-18	
		Quantity	Value	Quantity	Value
India		**35**	**4463**	**47**	**5685**
Private sector		35	4463	47	5685
Rajasthan					
Chittorgarh	HZL	35	4463	47	5685
Rajsamand	Chanderiya	35	4463	47	5685
Udaipur	Dariba Debari				

RECYCLING

National Waste and Recycling Associations (NWRAs) have been created around the world to promote the collection and recycling of all batteries, both from the general public and industrial consumers. Nickel-cadmium batteries which account for about three-fourths of the cadmium consumed, are virtually 100 percent recyclable once they have been collected.

There are 9 major NiCd battery recycling plants located in the United States of America, Europe and Japan. This includes copper-cadmium alloy scrap, some complex non-ferrous alloy scrap and cadmium containing dust from electric arc furnace. India imports cadmium & scraps. However, the details of the recycling units are not available.

SUBSTITUTES

Suitable replacements of cadmium in all uses, especially in pigments and plating are being contemplated and enforced owing to the pollution hazards associated with the use of cadmium. NiCd batteries, in some applications, are replaced with lead-acid, fuel cells lithium ion and nickel metal hydride batteries. However, higher costs of these substitutes restrict their uses. Cadmium in plating applications can be substituted by coatings of zinc or vapour-deposited aluminium. Cerium sulphide is used as a replacement for cadmium pigments mostly for plastics. Cadmium Telluride (CdTe) flexible thin film solar cells are an alternative to traditional crystalline silicon solar cells and are suitable for commercial roof top applications and large-scale ground mounted utility systems. CdTe photovoltaic cells are potentially safe, environment-friendly application for cadmium.

In India, cadmium is consumed in industries like paint, glass and chemical.

HEALTH AND SAFETY

Cadmium in all its chemical forms is considered highly toxic to living species as it does not decompose and is ingested easily through food, water and air but cannot be excreted. It is both bioaccumulated and biomagnified. Ingested cadmium accumulates in liver, kidney, pancreas and thyroid. Excessive exposure to cadmium has been linked with respiratory insufficiency (via occupational exposure) and renal disturbance (via environmental and occupational exposure). Cadmium has also been implicated in the development of cancer of various types.

During the last decade, regulatory pressure to reduce or even eliminate the use of cadmium has gained momentum in many developed countries. The world recommended target guidelines for cadmium as a residual heavy metal below which no major risk is expected which could have significant or adverse impact on aquatic biota or human use is 0.1 mg/l. In the USA, Federal and State agencies regulate cadmium content in the environment. Cadmium present in CRT screens, printer inks, toners, etc. is known to cause health hazards affecting the kidneys and causing flue like symptoms and muscular pain. In India, the Silver Jewellery Industry is an important cadmium consuming industry. Silver mixed with cadmium is used in the making of silver jewellery.

WORLD REVIEW

Cadmium is generally recovered from zinc ores and concentrates. Sphalerite, the most economically significant zinc ore mineral, commonly contains minor amounts of cadmium, which shares certain similar chemical properties with zinc and often substitutes for zinc in the sphalerite crystal lattice. The cadmium mineral greenockite is frequently associated with weathered sphalerite and wurzite. Zinc-bearing coals of the Central United States and Carboniferous age coals of other countries also contain large subeconomic resources of cadmium. Zinc-to-cadmium ratios in typical zinc ores range from 200:1 to 400:1. Quantitative estimates of reserves are not available. Cadmium content of typical zinc ore averages about 0.03%.

The world production of cadmium was estimated at 24,400 tonnes in 2017. Most of the world's primary cadmium is produced mainly in China, Republic of Korea, Japan, Canada, Kazakhstan, Mexico, Russia and Peru. As per mineral commodity summary, 2018 of USGS Report, the world refinery production of cadmium was estimated at 25,400 & 26,000 tonnes in 2017 & 2018 respectively.

World's secondary cadmium production accounted for 20% of the total metal production. Most secondary metal is produced at NiCd battery recycling facilities in Asia, Europe and the United States. China, Belgium and Japan are by far the world's largest consumers of cadmium. The world production of cadmium during 2015 to 2017 by principal countries. To give a generalised view of the development in various countries the country-wise description is sourced from latest available publication of Mineral Yearbook 'USGS' 2016 is furnished in Table-4.

Australia

In 2016, Nyrstar was in the process of increasing its crude cadmium production capacity at its lead smelter in Port Pirie, South Australia. The capacity expansion was part of a larger project at Port Pirie to enable the smelter to treat a wider range of feedstock and to update the facility's environmental controls. The new capacity was expected to be brought online in the first quarter of 2017. Port Pirie produced a crude cadmium product, which must be further refined to produce pure cadmium metal. Nyrstar's zinc smelter in Hobart, Tasmania was the sole producer of refined cadmium metal in Australia in 2016 (Metalpages, 2016a; Nyrstar NV, updated, p5,).

Belgium

Flaurea Chemicals [owned by Aurea SA (France)] used cadmium to produce cadmium compounds including cadmium chloride, nitrate and oxide and cadmium powder at its manufacturing facility in Ath. Cadmium compounds and powder were used mainly in coatings, paint pagments, NiCd batteries, PVC stabilizers, surface treatments, and thin-film solar panels. In 2016, Belgium imported 2,890 t of cadmium, mostly from France, Mexico, the Netherlands and Poland (Global` Trade information services Inc., 2017; Flaurea Chemicals, undated).

Canada

Teck Resources Ltd produced refined cadmium metal and cadmium compounds at its metallurgical complex in Trail, British Columbia. Cadmium metal products included balls, billets and sticks for NiCd battery manufacturing and continuously cast cadmium sheet for radiation shielding. HudBay Minerals Inc.'s copper smelting and zinc refining operations in Flin Flon, Manitoba, also produced cadmium metal. In 2016, Canada produced 2,305 t of cadmium, almost twice as much as in 2015 and exported 2,120 t mostly to China (71%) and Sweden (21%) (Global Trade Information Services Inc., 2017).

Table – 4 : World Mine Production of Cadmium (By Principal Countries)

(In tonnes)

Country	2015	2016	2017
World: Total	**24900**	**25800**	**24400**
Bulgaria	344	362	333
Canada	1159	2305	1802
China	8162	8222	8200[e]
Germany[e]	400	400	400
Japan	2188	1989	2142
Kazakhstan	1475	2682	1500[e]
Korea, Rep. of	5600[e]	4000	4000
Mexico	1283	1244	1142
Netherlands[e]	620	620	620
Norway	310[e]	335[e]	416
Peru	757	820	797
Poland	383	319	309
Russia[e]	1300	1600	1700
USA[e]	500	400	550
Other countries	419	502	489

Source: *World Mineral Production, 2013-17, BGS.*

Korea, Republic of

Korea Zinc's Onsan zinc-lead refinery had the capacity to produce 3,000 t/yr of refined cadmium and Young Poong Crop.'s Sukpo zinc refinery had the capacity to produce 1,750 t/yr of cadmium. Most of the cadmium produced in the Republic of Korea was exported to China and India (Global Trade Information Services Inc., 2017; Young Poong Corp., 2017,p.16;Korea Zinc Co. Ltd., undated,p.6)

Mexico

The Instituto Nacional de Estadística y Geografía (2017) reported that Mexico produced about 1,188 t of cadmium in 2016, 7% less than that in 2015. According to data reported by the two known producers, the total cadmium production in 2016 was about 1,280 tonnes. Industrias Peñoles S.A.B. de C.V.'s Met-Mex metallurgical complex in Torreon produced 579 t of cadmium in 2016, 13% less than that in 2015, and grupo Mexico S.A.B. de C.V.'s zinc smelter in San Luis Potosi produced about 700 t of cadmium in 2016, slightly more than that in 2015. Most of Mexico's cadmium production was exported to Belgium,China and the United Kingdom (Global Trade Information Services Inc., 2017; Industrias Penoles S.A.B de C.V., 2017; Instituto Nacional de Estadistica y Geografia, 2017; Southern Copper Corp., 2017, p.54).

FOREIGN TRADE

Exports

Exports of Cadmium (including waste & scrap) decreased to 199 tonnes during 2017-18 from that of 237 tonnes in the previous year. Exports were mainly to Bangladesh (95%) and Pakistan (4%).

Exports of cadmium & alloys increased to 174 tonnes during 2017-18 as against 159 tonnes in the previous year. Exports of cadmium & scrap increased considerably at 18 tonnes as against one tonne in the previous year. Exports of cadmium unwrought and powders decreased drastically to 7 tonnes as compared to 77 tonnes in the previous year (Tables-5 to 8).

Imports

Imports of cadmium (including waste & scrap) increased slightly to 6,519 tonnes in 2017-18 from 4,737 tonnes in the previous year. The imports comprised 5,409 tonnes unwrought, powders and 1110 tonnes scrap besides nominal quantity of cadmium and alloys in 2017-18. Imports were mostly from Korea, Rep.of (23%), Japan (25%), Peru and Mexico (8% each), Russia (7%), Australia and France (5% each), Uzbekistan (4%) and China (2%) (Tables-9 to 12).

Table – 5: Exports of Cadmium (Including Waste & Scrap)
(By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**237**	**19876**	**199**	**20076**
Bangladesh	162	11334	189	18438
Pakistan	++	105	8	1256
UAE	++	72	1	148
Indonesia	-	-	++	72
Nepal	-	-	1	68
Iran	-	-	++	53
Iraq	-	-	++	30
Labanon	-	-	++	9
Sri Lanka	-	-	++	1
Philippines	++	2	++	1
Other countries	75	8363	-	-

Table – 6: Exports of Cadmium & Alloys (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**159**	**11537**	**174**	**17015**
Bangladesh	159	11223	169	16256
Pakistan	-	-	3	464
UAE	++	65	1	134
Nepal	-	-	1	68
Iran	-	-	++	53
Iraq	-	-	++	30
Lebanon	-	-	++	9
Philippines	-	-	++	1
Other countries	++	249	-	-

Table – 7: Exports of Cadmium & Scrap (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1**	**252**	**18**	**2485**
Bangladesh	-	-	13	1607
Pakistan	-	-	5	792
Indonesia	-	-	++	72
UAE	++	7	++	14
Algeria	1	201	-	-
Tunisia	++	44	-	-

Table – 8: Exports of Cadmium :Unwrought, Powders (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**77**	**8087**	**7**	**576**
Bangladesh	3	111	7	575
Sri Lanka	-	-	++	1
Saudi Arabia	2	415	-	-
Malaysia	++	1	-	-
China	72	7453	-	-
Pakistan	++	105	-	-
Philippines	++	2	-	-

Table – 9: Imports of Cadmium (Including Waste & Scrap) (By Countries)

Country	2016-17 Qty (t)	2016-17 Value (`'000)	2017-18 Qty (t)	2017-18 Value (`'000)
All Countries	**4737**	**446607**	**6519**	**800453**
Korea, Rep. of	1936	188945	1525	201321
Japan	773	75040	1614	197642
Mexico	82	7237	517	63782
Peru	514	47617	550	61797
Russia	478	40363	426	58042
Australia	100	9487	340	42099
France	155	14206	312	36234
Bulgaria	-	-	265	31451
Uzbekistan	277	24229	259	29071
China	1	2870	160	18334
Other countries	421	36613	551	60680

Table – 10 : Imports of Cadmium & Alloys (By Countries)

Country	2016-17 Qty (t)	2016-17 Value (`'000)	2017-18 Qty (t)	2017-18 Value (`'000)
All Countries	**++**	**91**	**++**	**208**
Germany	++	28	++	82
UK	++	21	++	73
China	-	-	++	27
USA	++	42	++	26

Table – 11: Imports of Cadmium: Unwrought, Powders (By Countries)

Country	2016-17 Qty (t)	2016-17 Value (`'000)	2017-18 Qty (t)	2017-18 Value (`'000)
All Countries	**3798**	**353270**	**5409**	**659811**
Japan	674	65803	1298	160492
Korea, Rep. of	1257	121474	1135	148252
Mexico	82	7237	517	63782
Peru	380	35310	532	59720
Russia	478	40363	383	51407
France	155	14206	312	36234
Bulgaria	-	-	265	31451
Australia	100	9487	240	29343
Uzbekistan	254	22365	259	29071
Germany	-	-	78	10521
Other countries	418	37025	390	39538

Table – 12 : Imports of Cadmium & Scrap (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**939**	**93246**	**1110**	**140434**
Korea, Rep. of	679	67471	390	53069
Japan	99	9237	316	37150
China	++	715	160	18307
Australia	-	-	100	12756
Russia	-	-	43	6635
Netherlands	-	-	38	5063
Korea, Dem. P.R.	-	-	20	2501
Brazil	-	-	25	2460
Peru	134	12307	18	2077
Belgium	-	-	++	414
Other countries	27	3516	++	2

FUTURE OUTLOOK

The world cadmium market based on the world production of cadmium does indicate a fluctuate trend. While the primary cadmium supply is on decrease, there is a modest rise in production through recycling. Though, cadmium consumption in various applications is clamoured with concerns over its toxicity and hazardous effect on human health and environment, the production of cadmium as a by-product will however continue as long as lead and zinc are produced.

The demand for cadmium is increasing owing to several new market opportunities for NiCd batteries, particularly in industrial applications. NiCd battery had been favoured for use in less expensive consumer appliances and elecrtonics owing to their cost advantage over other battery chemistries. During the past few years, lithium-ion batteries have significantly replaced NiCd batteries in some low-cost electronics and substitution is expected to continue as the manufacturing cost of lithium-ion batteries decreases and their electrical storage capacity increases.

NiCd batteries, however, are expected to continue to be used in certain industrial applications because of their superior reliabilility and stability compared with the other rechargeable battery technologies. NiCd batteries power some battery-powered electric vehicles and are also used in a limited number of hybrid electric vehicles. NiCd batteries also are used as buffers in transportabe, renewable hybrid-power systems developed to generate electricity in remote locations and in underdeveloped regions. Industrial-sized NiCd batteries potentially could be used to store energy produced by certain on-grid solar or wind systems. Excess energy generated during periods of low electricity demand could be stored in batteries, from which it would later be dispatched during periods of high electricity demand. NiCd may be a favoured battery chemistry for this use owing to its stability in offshore and harsh weather environments. NiCd battery is used in electrical vehicles albeit in limited number in hybrid electrical vehicles and has been making important contribution to the development of the electric car market in Europe.

Candium pigments and stabilisers are important additives in certain specialised plastic, glasses, ceramics and enamels wihch enable to achieve bright colours along with long service life, even in very demanding applications. It should also be emphasised that cadmium in these applications is in a chemically very stable, highly insoluble form and is embedded in the product matrix.