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BORON MINERALS

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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4 Boron Minerals

Boron minerals occur mostly as borates which are deposited from volcanic gases or hot springs near volcanic activities. The deposits, predominantly of borax and sassolite are formed as a result of drying up of shallow saline and alkaline tertiary lakes called 'Playa'. The principal boron minerals are borax, hydrated sodium borate ($Na_2O.2B_2O_3.10H_2O$), kernite (rasorite), hydrated sodium borate ($Na_2O.2B_2O_3.4H_2O$), colemanite, hydrated calcium borate ($Ca_2B_6O_{11}.5H_2O$), and ulexite, hydrated sodium calcium borate ($NaCaB_5O_9.8H_2O$). Besides, the above four boron minerals of commercial importance, two minerals, viz., sassolite (H_3BO_3), the natural boric acid and boracite ($Mg_3B_7O_{13}Cl$) are less important.

Borax is, presently, not produced in India. However, it was obtained since ancient times from the Lakes in Jammu & Kashmir in India. The domestic requirements of boron minerals are met solely through imports of crude borate which is refined in the country for producing borax and boric acid.

RESERVES/RESOURCES

Economically viable deposits of borax have not been established in the country so far. The only deposit of little economic significance is reported from Puga Valley in Leh district, Jammu & Kashmir. As per NMI data, based on UNFC system, total reserves/resources of borax as on 1.4.2015, have been estimated at 74,204 tonnes in Jammu & Kashmir. All resources are of reconnaissance category viz., UNFC Code 334. Occurrences are also reported from Surendranagar district, Gujarat and Nagaur district, Rajasthan. The bittern obtained from Sambar Lake in Jaipur district, Rajasthan, also contains about 0.5% borax (Table-1).

USES

Glass and porcelain industries are the major consumers of borax and boric acid. It is an essential component of heat-resisting boro-silicate glass, glass fibres and industrial & optical glass. In glass, enamels and ceramics, it controls thermal expansion, improves durability, assists melting processes and adds to inorganic colours and decorations.

Borax is used in medicine (boric powder), leather processing, adhesive, corrosion inhibition, ferrous wire manufacture, flame-proofing and timber preservation.

Borax is used as a flux in brazing, welding, soldering and in the manufacture of artificial gems like, cubic boron nitride, (commercially called 'Borazon') which is equal to diamond in hardness and boron carbide, titanium boride and tungsten boride which are next to diamond in hardness.

Its easy solubility and property to soften hard water find applications in soaps, cleaners & detergents and for water treatment. Because of its mild alkalinity and germicidal nature, it is used in manufacturing toothpastes and mouth washes. Borax is used as an antiseptic and emulsifying agent in cosmetics industry. As a decolourising agent, it is used in vanaspati industry. In textile industry, borax is used as a decolourising agent as well as for maintaining the alkalinity of solutions used for producing rayons. It prevents mould formation in citrus fruits. In agriculture, borax is used as an essential plant nutrient.

Boron compounds are used for fertilizers, algicides, herbicides and insecticides. Borax and boric acid are used in fire-retardant treatment and as food grain preservative, respectively.

Borate ester is used as dehydrating agent, special solvent and catalyst in chemical industry. In nuclear reactor, boron acts as neutron absorber. "Boron neutron capture therapy", a form of radiochemotherapy, is becoming increasingly important for treatment of certain forms of cancers and boron neutron capture synovectomy for treatment of arthritis.

Borates are consumed mainly in glass fibre for insulations and textile-grade fibre. They are also used as anti-knock agents in gasoline. Diborane (gas), pentaborane (liquid) and decaborane (solid) are potential jet and rocket engine fuels. Boron hydride also has potential value as rocket fuel. The high energy fuel value imparted by the addition of boron compounds has given considerable strategic significance to borates. Another use of borates is the invention of oxgano-sodium borate (liquibor) for use in hydraulic brake fluids.

Table – 1 : Reserves/Resources of Borax as on 1.4.2015
(By Grades/States)

(In tonnes)

Grade/State	Reserves	Remaining Resources						Total Resources (A+B)
	Total (A)	Pre-feasibility STD221	Measured STD331	Indicated STD332	Inferred STD333	Reconnaissance STD334	Total (B)	
All India : Total	-	-	-	-	-	**74204**	**74204**	**74204**
By Gades								
Unclassified	-	-	-	-	-	74204	74204	74204
By States								
Jammu & Kashmir	-	-	-	-	-	74204	74204	74204

Figures rounded off.

Substitutes

Substitutes in applications such as soaps, detergents, enamels and insulations are available. In detergents, boron compounds can be replaced with chlorine and enzymes. Lithium compounds can be used to make enamels and glass products. Insulation substitutes include cellulose, foams and mineral wools. Substitution of borosilicate glass by plastic materials may reduce the use of boron.

Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamels can use other glass-producing substances, such as phosphates. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

Technical Possibilities

A proprietary process called 'Hydrogen on Demand' has been developed using water and sodium borohydride. Hydrogen from the system can be used in fuel cells or internal combustion engines. A longer-life battery based on boron has also been designed. Synthetic diamond containing about 3% boron which is normally a semiconductor becomes superconductor at 4 K. Boron-doped diamond, thus, has numerous possible applications as it can carry electricity without resistance.

Improvements made in evaporating brine solutions are widening the choice of source. Production of boric acid through solution mining of colemanite is a possibility.

Environmental Concern

Natural borates are not very toxic to animals but can be toxic to plants even though low levels of boron are essential for plant life. Boron-hydrogen compounds known as boranes which do not occur in nature are highly toxic and have posed problems in some industrial applications. Environmental concerns have hastened substitution in soaps and detergents. In Europe, borates continue to be listed under hazardous substances and the risk evaluated for their safety under conditions of normal handling and use related to classification and labelling already exists. The US Food and Nutrition Board announced that the essentiality data on boron was adequate to establish a daily tolerable Upper Intake Level for an adult at 20 mg boron.

INDUSTRY

In borax manufacturing process, crude sodium borate is dissolved in water, charged, oxidised, crystallised and centrifuged. Centrifuged material is then dried to get borax decahydrate.

Crude calcium borate lumps are crushed and wet-ground with mother liquor to make slurry. This slurry is decomposed with sulphuric acid to give calcium sulphate and boric acid. Boric acid is separated by filtration, purified, cooled and centrifuged to produce boric acid granules which are powdered as per demand.

Borax Morarji Ltd, Ambernath, Thane district, Maharashtra, is engaged in refining of imported crude borates to produce borax and boric acid. **The annual production capacity for all grades of Borax and Boric Acid are 24,000 MT at Dahej, GIDC in the state of Gujarat**. National Peroxide Limited, Vadavali, Kalyan district, Maharashtra, produces sodium perborate which is used as a bleaching agent. **National Peroxide Limited (NPL) is the manufacturer of hydrogen peroxide in India, with an installed capacity of 95,000 MTPA.** Indo Borax and Chemical Limited operates borax and boric acid plants at Pithampur, Madhya Pradesh.

Ferro-boron is a boron ferro-alloy containing 0.2% to 24% boron used primarily to introduce small quantities of boron into speciality steels. Domestic production of ferro-boron was 42 tonnes in 2014-15 and data for 2015-16 is not available.

CONSUMPTION

The consumption of borax in the organised sector in 2015-16 remained at the same level as in 2014-15 i.e. at 23,100 tonnes. Chemical and glass industries were the major consumers accounting for about 93% borax consumption (Table-2).

Table – 2 : Estimated Consumption* of Borax, 2013-14 to 2015-16 (By Industries)

(In tonnes)

Industry	2013-14 (R)	2014-15 (R)	2015-16 (P)
All Industries	**22900**	**23100**	**23100**
Ceramic	800	800	800
Chemical	19900	19900	19900
Glass	1400	1600	1600
Graphite products	100	100	100
Others (abrasive, cosmetics, paint, paper, pharmaceutical, refractory, textile and vanaspati)	700	700	700

Figures rounded off.

** Includes actual reported consumption and/or estimates made wherever required and due to paucity of data, coverage may not be complete.*

WORLD REVIEW

The estimated world reserves of boron minerals are about 1100 million tonnes in terms of boric oxide. Countries with sizeable resources are **Turkey (86%), USA & Russia (4% each), Chile & China (3% each)**. The world reserves of boron in terms of boric oxide are given in Table-3.

Turkey is the leading producer of borates accounting for 36% of total world production followed by USA (21%), Argentina (13%) and Peru (11%) during 2015. Apart from these, substantial quantities of borates are also produced by Chile, Russia, Bolivia and China (Table-4).

Turkey

Approximately 73% of the world's boron reserves are in Turkey with average B_2O_3 content ranging from 26 to 31 percent.The Kirka deposit at Eskisehir reported to be the largest boron deposit in the world. The main borate producing areas of Turkey, all controlled by the state-owned mining company Eti Maden AS, are bigadic (colemanite and ulexite), Emet (colemanite), Kestelek (colemanite, probertite, and ulexite), and Kirka (tincal). Production of refined borates increased during the past few years owing to continued investment in new refineries and technologies. A recent examination of plant species in boron-rich areas of Turkey revealed a number of indicator plants, which may be used for boron prospecting in Turkey or in similar biome areas elsewhere in the world.

Argentina

Argentina was the second-leading producer of boron minerals in South America in 2015. Borate deposits are located primarily in the Puna region, which includes the northwestern tip of Argentina, the southeastern corner of Peru, the southwestern corner of Bolivia and the northeastern border of Chile. The principal markets for borates produced in Argentina were Brazil and, to a lesser degree, domestic consumers.

Borax Argentina S.A, the country's leading producer of borates, operated the Tincalayu Mine, the largest open pit operation in the country, which is 4,100 m (13,500 feet) above sea level. The deposit consisted primarily of borax, with rare occurrences of ulexite and 15 other borates.

Minera Santa Rita S.R.L (MSR) operated mines in Catamarca, Jujuy, and Salta Provinces and operated a processing plant in Campo Quijano, which produced various grades and sizes of natural boron minerals. MSR exported 97% of its mined borates to 30 countries through the Port of Buenos Aires and by land to Brazil.

Chile

Chile was the major borate producer in South America with 518,000 tonnes of borates, primarily ulexite, in 2015. The largest ulexite deposit in the world, Salar de Suirire, was operated by Quimica e Industrial del Borax Ltd, a Govt. entity with reserves estimated at 1.5 million tonnes. Almost all the material mined at this location was exported in 2015.

China

China has low-grade boron resources and demand for boron is expected to increase. Imports from Chile, Russia, Turkey and the United States are expected to increase during the next several years. More than 100 borate deposits occur in 14 Provinces in China. The northeastern Province of Liaoning and the western Province of Qinghai accounted for more than 80% of the resources, mostly in the form of sassolite and tincal. China's boron resources are of low quality, averaging about 8% B_2O_3.

Serbia

A Canadian mining and exploration company, Erin Ventures Inc., initiated proceedings to begin borate mining in Piskanja, a mining region in Serbia approximately 250 km south of Belgrade. The deposit is primarily composed of colemanite and ulexite with estimated reserves of 11.8 million tonnes at an average B_2O_3 content between 29% and 31%. Mining did not commence in 2015 but was expected to begin in the near future.

Table – 3 : World Reserves of Boron (By Principal Countries)

(In '000 tonnes of boric oxide)

Country	Reserves
World: Total (rounded)	**1100000**
Chile	35000
China	32000
Peru	4000
Russia	40000
Turkey	950000
USA	40000

Source: USGS, MCS-2018

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

(In '000 tonnes)

Country	2013	2014	2015
World: Total	**5122**	**6513**	**6039**
Argentina[e]	670	740	770
Bolivia	157	152	166
Chile	581	497	518
China[e]	160	160	160
Peru	224	240	663
Russia[e]	250	250	250
Turkey	1748	3143	2181
USA[e]	1300	1300	1300
Other countries	32	31	31

Source: *World Mineral Production, 2011-2015.*

FOREIGN TRADE

Exports

Exports of borax (total) decreased to 1,724 tonnes in 2015-16 from 2,655 tonnes in the previous year. Exports of natural borate in 2016-17 decreased considerably to 65 tonnes as compared to previous year. In 2015-16, exports of sodium borate were 1,135 tonnes and other borates 448 tonnes. Exports of Borax (total) were mainly to Iran, USA, Bangladesh and UAE. Exports of boric acid decreased to 1,000 tonnes in 2015-16 from 1,282 tonnes in the previous year. Exports were mainly to Iran, Nigeria, USA and Thailand (Tables- 5 to 10).

Imports

Imports of borax (total) decreased significantly to 1,33,551 tonnes in 2015-16 from 1,46,301 tonnes in the previous year. Imports in 2016-17 for natural borate decreased to 51,976 tonnes as compared to previous year. In 2015-16, imports for sodium borate were75,974 tonnes and other borates 3,604 tonnes. Borax (total) was mainly imported from Turkey, USA, Spain, Bolivia, China and Chile. Imports of boric acid also decreased to 15,183 tonnes in 2015-16 from 17,305 tonnes in the previous year. Boric acid was imported mainly from USA,Turkey and Peru. Similar to that of the previous year in 2015-16 too import of boron was negligible (Tables- 11 to 17).

Table – 5 : Exports of Borax : Total (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**2655**	**164669**	**1724**	**124646**
USA	149	25059	143	26291
Bangladesh	106	13527	317	20289
Iran	691	31729	317	13921
UAE	122	4644	261	10818
Sri Lanka	22	16691	31	9917
Australia	18	2930	63	9839
Italy	-	-	38	4316
Thailand	88	3440	103	4284
Germany	++	63	11	3899
Myanmar	68	2862	88	3893
Other countries	1391	63724	352	17179

Table- 6: Exports of Natural Borate (By Countries)

Country	2016-17 (P)	
	Qty (t)	Value (₹'000)
All Countries	**65**	**1329**
Nepal	13	798
UAE	52	432
Other countries	++	99

Source: Import-Export data bank, ministry of commerce, HS Code-252800

Table – 7 : Exports of Natural Borate (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**102**	**1026**	**141**	**1513**
Vietnam	-	-	25	546
Nepal	101	837	61	437
Kenya	-	-	50	414
UAE	-	-	4	87
Rwanda	-	-	++	15
South Africa	++	1	1	8
Bahrain	++	69	++	3
USA	-	-	++	3
Uganda	1	118	-	-
Jordan	++	1	-	-

Table – 8 : Exports of Sodium Borate (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**2114**	**95148**	**1135**	**51517**
Iran	685	30946	312	13250
UAE	122	4622	255	10426
Bangladesh	1	49	224	7640
USA	5	679	14	4127
Mayanmar	48	2052	88	3893
Saudi Arabia	100	4248	80	3635
Thailand	40	1966	61	2980
Oman	5	769	11	1913
Nepal	93	3834	43	1715
Jordan	6	259	20	764
Other countries	1009	45724	27	1174

Table – 9 : Exports of Borax : Other Borates (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**439**	**68525**	**448**	**71616**
USA	144	24380	129	22161
Bangladesh	105	13478	93	12649
Australia	18	2930	62	9832
Sri Lanka	22	16691	10	9210
Italy	-	-	38	4316
Germany	++	62	11	3883
UK	31	4629	20	3013
France	++	7	10	1818
Thailand	48	1474	42	1304
South Africa	-	-	7	681
Other countries	71	4874	26	2749

Table – 10 : Exports of Boric Acid (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1282**	**91951**	**1000**	**81558**
Iran	210	12186	351	19912
Nigeria	400	31347	200	17138
USA	25	3323	45	6853
Nepal	30	3135	38	3643
Jordan	43	3595	28	2688
Saudi Arabia	8	580	28	2366
UAE	11	873	26	2200
Japan	20	1801	22	2175
Sudan	18	2532	20	2169
Thailand	105	4811	43	2095
Other countries	412	27768	199	20319

Table – 11 : Imports of Borax : Total (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**146301**	**4474017**	**133551**	**4429452**
Turkey	93523	2593958	86031	2724129
USA	31282	1182208	25145	956583
Spain	7845	287943	9344	329496
Bolivia	8459	126150	7753	118754
China	1180	103310	1349	116456
Austria	805	54607	731	46126
Malaysia	250	10304	637	25166
Peru	226	8225	624	22125
Argentina	596	22829	325	20149
Chile	1566	24317	1053	18042
Other countries	569	60166	559	52426

Table- 12: Imports of Natural Borate (By Countries)

Country	2015-16 (P)	
	Qty (t)	Value (₹'000)
All Countries	**51976**	**1400792**
Turkey	42328	1115646
Spain	7632	246775
Chile	1566	27774
Iran	379	8844
UAE	50	862
Argentina	20	791
Japan	1	100

Source: *Import-Export data bank, Ministry of Commerce, HS Code-252800*

Table – 13 : Imports of Natural Borate (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**67430**	**1590619**	**53973**	**1413804**
Turkey	51006	1229669	37890	1054009
Spain	5612	184275	6968	215390
Bolivia	8459	126150	7753	118754
Chile	1566	24317	1053	18042
Iran	-	-	197	4025
Argentina	570	20723	112	3557
Japan	++	43	++	27
Serbia and Montenegro	99	2380	-	-
China	++	45	-	-
Unspecified	118	3002	-	-
Other countries	++	15	-	-

Table – 14 : Imports of Sodium Borate (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**75332**	**2586805**	**75974**	**2739108**
Turkey	42167	1348634	47812	1658259
USA	30205	1092012	24382	896234
Spain	2233	103416	2313	110821
Malaysia	160	4768	516	18703
Argentina	26	2106	213	16592
Peru	216	6556	483	16529
Netherlands	136	13835	106	11180
Singapore	39	1380	69	3415
UAE	-	-	74	2709
Germany	1	1538	1	2303
Other countries	149	12560	5	2363

Table – 15 : Imports of Borax : Other Borates (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**3539**	**296593**	**3604**	**276540**
China	1049	94042	1344	114662
USA	1077	90181	763	60349
Austria	805	54607	731	46126
UK	8	6761	14	12186
Turkey	350	15655	329	11860
Malaysia	90	5536	121	6463
Peru	10	1669	141	5596
Spain	++	252	63	3285
Australia	++	287	++	2944
Singapore	16	1381	32	2763
Other countries	134	26222	66	10306

Table – 16 : Imports of Boric Acid (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**17305**	**859435**	**15183**	**732379**
USA	6699	351444	6898	346192
Turkey	6669	324736	6302	291823
Peru	2914	133798	1575	73404
Russia	140	6505	220	9795
China	21	1955	90	6114
Chile	-	-	77	3573
Korea, Rep. of	-	-	20	898
Germany	2	620	++	325
Japan	-	-	1	154
Switzerland	-	-	++	50
Other countries	860	40377	++	51

Table – 17 : Imports of Boron (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1**	**2863**	**++**	**1281**
USA	++	1420	++	676
China	++	455	++	475
Japan	++	81	++	78
UK	++	192	++	48
Germany	++	38	++	4
Belgium	++	439	++	-
Ialy	1	238	++	-

FUTURE OUTLOOK

Consumption of borates is expected to increase, spurred by strong demand in agriculture, ceramic and glass markets in Asia and South America. Continued investment in new refineries & technologies and the continued increase in demand were expected to fuel growth in world production during the next several years. In 2013, the European Union (EU) added borates to the Registration, Evaluation, Authorisation and Restrictions of Chemicals (REACH) Restricted Substances List (RSL), following an EU study that determined continuous exposure may be harmful. The ruling required detergent makers to decrease their use of boron. Consumption of boron-based fertilizers is expected to increase as the demand for food and biofuel crops also increases. Higher crop prices have enabled farmers to invest more capital in advanced farming techniques and higher grade fertilizers. Consumption of borates by the Ceramics Industry is expected to shift away from Europe to Asia, which accounted for the majority of world demand for ceramics in 2015.

Consumption of boron nitride is expected to increase due to the development of high-volume production techniques coupled with the creation of new technologies requiring boron nitride. The properties intrinsic to cubic boron nitride, such as hardness (second only to diamond), high thermal conductivity and oxidation resistance, make it an ideal material in a variety of emerging applications. Hexagonal boron nitride is used in additives, ceramics and intermetallic composites, imparting thermal shock resistance, improved machinability and reduction of friction.