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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 Jaipur district, Rajasthan (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.

Boron is an essential plant nutrient and boron compounds such as borax and boric acid are used as fertilizers in agriculture, although they are only required in samll amounts, with excess being toxic.

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 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. Apart from two other producers, National Peroxide Limited (NPL) located at Kalyan district, Maharashtra, is the largest producer of Hydrogen Peroxide in the country. During financial year ending March, 2018, total production of all the three producers in the country is estimated at 200,000 MT. NPL is a pioneer in Hydrogen Peroxide industry in India and has been at the forefront in development of technology, brand image and market share in the country. Indo Borax and Chemical Limited operates borax and boric acid plants at Pithampur, Madhya Pradesh.

Ferroboron is a boron ferroalloy containing 0.2% to 24% boron used primarily to introduce small quantities of boron into speciality steels. Domestic production of ferroboron was reported at 42 tonnes in 2014-15 and data for 2015-16, 2016-17 & 2017-18 is not available.

WORLD REVIEW

The estimated world reserves of boron minerals are about 1093 million tonnes in terms of boric oxide. Countries with sizeable resources are Turkey (87%), USA & Russia (4% each), Chile (3%) & China (2%). The world reserves of boron in terms of boric oxide are given in Table-2.

Turkey was the leading producer of borates followed by Chile, Kazakhstan, Argentina, Bolivia , Russia & China during 2017 (Table-3).

To give a generalised view of the development in various countries the coutry-wise description is sourced from latest available publication of Minerals Yearbook 'USGS' 2016 and the same is furnished below.

Turkey

Approximately 87% 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 tincal 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 2016. 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 the majority of its mined borates to 28 countries through the Port of Buenos Aires and by land to Brazil.

Chile

Chile was the major borate producer in South America with production of 36,000 tonnes of boric acid in addition to 100,000 tonnes of borate-derived agrochemical products. The largest ulexite deposit in the world, Salar de Suirire, was operated by Quiborax SA, a Govt. entity with reserves estimated at 1.5 million tonnes. Almost all the material mined at this location was exported in 2016.

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. Exploration began in early 2016 with two drillholes that indicated B_2O_3 content between 22% to 35%.

Table – 2 : World Reserves of Boron (By Principal Countries)

(In '000 tonnes of boric oxide)

Country	Reserves
World: Total (rounded off)	**1093000**
Chile (Ulexite)	35000
China (Boric oxide equivalent)	24000
Peru (Crude borate)	4000
Russia (Datolite ore)	40000
Turkey (Concentrate)	950000
USA	40000

Source: *Mineral Commodity Summaries,2019, USGS.*

Table – 3: World Production of Borates (By Principal Countries)

(In '000 tonnes)

Country	2015	2016	2017
Argentina[e]	480	520	519
Bolivia	166	200	174
Chile	518	559	607
China[eb]	90	90	90
Kazakhstan[e]	500	510	500
Peru	663	34	-
Turkey	2181	2070	2495
USA[a]	1300	1300	1300
Russia	80	80	80

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

a: Soblor used by producers, b: B_2O_3 equivalent.

FOREIGN TRADE

Exports

Exports of borax (total) increased to 3,136 tonnes in 2017-18 from 2,480 tonnes in the previous year. Exports of natural borate in 2017-18 decreased considerably to 16 tonnes as compared to 65 tonnes in previous year. In 2017-18, exports of sodium borate were at 2,084 tonnes and other borates 1,036 tonnes. Exports of Borax (total) were mainly to Malaysia (45%), Italy & USA (13% each), Syria (8%), Myanmar (4%) and Bangladesh (3%). Exports of boric acid decreased to 1,379 tonnes in 2017-18 from 1,872 tonnes in the previous year. Exports were mainly to Iran (22%), Nigeria (20%), USA (6%) and Nepal (5%) (Tables-4 to 9).

Imports

Imports of borax (total) increased by 24% to 1,60,134 tonnes in 2017-18 from 1,29,407 tonnes in the previous year. Imports of natural borate also increased by 41% to 73,386 tonnes as compared to 51,976 tonnes in the previous year. In 2017-18, imports of sodium borate were at 76,415 tonnes and other borates 10,333 tonnes. Borax (total) was mainly imported from Turkey (68%), USA (22%), Spain (6%), Bolivia (3%) and China (1%). Imports of boric acid substantially decreased by 64% to 7,412 tonnes in 2017-18 from 20,529 tonnes in the previous year. Boric acid was imported mainly from USA (47%),Turkey (40%) and Peru (11%). On the other hand, imports of boron was only one tonne in both the years (Tables-10 to 15).

Table – 4 : Exports of Boron (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1**	**14**	**++**	**26**
Bangladesh	1	14	-	-
USA	-	-	++	26

Table – 5 : Exports of Borax (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**2480**	**164054**	**3136**	**261791**
USA	98	21016	401	63049
Malaysia	763	35635	1418	60207
Italy	140	15508	400	51026
Bangladesh	92	13157	105	15048
Australia	20	3143	70	13201
Syria	-	-	236	8943
Sri Lanka	58	10286	10	6384
Oman	40	6496	28	6065
Myanmar	20	865	136	5592
UK	++	++	7	4622
Other countries	1249	57948	325	27654

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

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**65**	**1329**	**16**	**560**
Nepal	13	798	14	407
Zambia	-	-	1	72
Rwanda	-	-	1	36
Bhutan	-	-	++	34
Sri Lanka	-	-	++	10
Singapore	-	-	++	++
UAE	52	432	-	-
Kuwait	++	++	-	-
Qatar	++	90	-	-
Other countries	++	9	-	-

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

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1969**	**93325**	**2084**	**98828**
Malaysia	763	35635	1418	60195
USA	13	7182	99	13000
Syria	-	-	236	8943
Myanmar	20	865	136	5592
Thailand	350	13032	100	4312
Nepal	165	8943	22	2163
Saudi Arabia	++	2	40	1665
Mauritius	++	1	9	1184
Jordon	12	431	6	254
Zambia	2	293	5	250
Other countries	644	26941	13	1270

Table – 8 : Exports of Borax: Other Borates (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**446**	**69400**	**1036**	**162403**
Italy	140	15508	400	51026
USA	85	13834	302	50049
Bangladesh	92	13110	105	15004
Australia	20	3124	70	13050
Sri Lanka	16	8844	10	6353
Oman	17	2705	28	6065
UK	++	++	7	4622
UAE	8	1586	23	3564
France	20	3368	20	3275
China	++	69	20	3070
Other countries	48	7252	51	6325

Table – 9: Exports of Boric Acid (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1872**	**116916**	**1379**	**100727**
Nigeria	388	22346	276	16393
Iran	555	30841	298	13366
USA	45	7387	78	12642
Nepal	52	5319	75	6058
Bangladesh	11	1238	62	3191
Saudi Arabia	35	2802	42	3164
Tanzania	9	824	38	2654
Kenya	27	2648	37	2618
Cameroon	24	2713	30	2580
Djibouti	-	-	28	2542
Other countries	726	40798	415	35519

Table – 10: Imports of Borax (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**129407**	**4359797**	**160134**	**4753976**
Turkey	84318	2594725	106779	2888031
USA	30315	1126708	34704	1149618
Spain	8859	308544	10078	354737
China	1309	119275	1273	122898
Bolivia	-	-	4120	57340
Peru	681	32088	856	47331
Argentina	290	16116	798	35621
Austria	436	30355	452	32023
Netherlands	184	18680	186	19222
Iran	379	8844	482	8030
Other countries	2636	104462	406	39125

Table – 11: Imports of Natural Borate (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**51976**	**1400792**	**73386**	**1713685**
Turkey	42328	1115646	59978	1352874
Spain	7632	246775	8669	291038
Bolivia	-	-	4120	57340
Iran	379	8844	482	8030
Argentina	20	791	80	3039
Russia	-	-	30	829
Chile	1566	27774	27	491
Japan	1	100	++	38
Italy	-	-	++	6
UAE	50	862	-	-

Table – 12: Imports of Sodium Borate (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**67230**	**2417843**	**76415**	**2486188**
Turkey	37671	1322918	42048	1346294
USA	26798	959888	31833	1014287
Spain	1227	61520	1241	56637
Argentina	162	6467	607	24128
Netherlands	174	18360	186	19222
Peru	487	19339	354	14967
Malaysia	456	16121	99	4302
Germany	1	2772	3	3563
UAE	2	183	20	1927
China	9	1299	23	630
Other countries	243	8976	1	231

Table – 13: Imports of Borax: Other Borates (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**10201**	**541162**	**10333**	**554103**
Turkey	4319	156161	4753	188863
USA	3517	166820	2871	135331
China	1300	117976	1250	122268
Peru	194	12749	502	32364
Austria	436	30355	452	32023
Argentina	108	8858	111	8454
Spain	++	249	168	7062
Slovenia	91	4654	147	6971
Japan	7	5581	7	6712
Italy	8	1526	32	5910
Other countries	221	36233	40	8145

Table – 14: Imports of Boric Acid (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**20529**	**897345**	**7412**	**304862**
USA	6936	301863	3511	141362
Turkey	5675	264992	2969	123945
Peru	3098	128755	832	32600
China	60	3901	100	6431
Germany	++	1306	++	378
Italy	2	431	++	110
Sweden	-	-	++	18
Belgium	++	13	++	17
France	-	-	++	1
Spain	105	3586	-	-
Other countries	4653	192498	-	-

Table – 15: Imports of Boron (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1**	**9076**	**1**	**7701**
China	1	6500	1	6210
USA	++	1986	++	643
Belgium	++	264	++	622
Japan	++	101	++	116
UK	++	37	++	96
Germany	++	2	++	14
Canada	++	186	-	-

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.