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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, the total reserves/resources of borax as on 1.4.2015, has 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

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 Grades								
Unclassified	-	-	-	-	-	74204	74204	74204
By States								
Jammu & Kashmir	-	-	-	-	-	74204	74204	74204

Figures rounded off

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 small amounts, with excess being toxic.

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 CONCERNS

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 the year 2018-19, NPL achieved a capacity utilisation of 106.60% of the installed capacity of Hydrogen peroxide, as compared to 108.50% during the previous year. The project for expansion of the Hydrogen Peroxide plant capacity from 95,000 MTPA to 1,50,000 MTPA is under progress and is scheduled to be completed during the financial year 2019-20.

During financial year ending March, 2018, the total production of all the three producers in the country is estimated at 2,00,000 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 ferro alloy containing 0.2% to 24% boron used primarily to introduce small quantities of boron into speciality steels.

WORLD REVIEW

The world reserves of boron in terms of boric oxide are furnished in Table-2.

Turkey was the leading producer of borates followed by USA, Argentina, Kazakhstan, Chile, Bolivia and Peru.

To provide a generalised view of the development in various countries, the contrywise description sourced from latest available publication of Minerals Yearbook 'USGS' 2017 has been furnished as below.

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

(In '000 tonnes of boric oxide)

Country	Reserves
World: Total(1)	**xx**
Argentina, crude ore	NA
Bolivia, ulexite	NA
Chile, ulexite	35000
China, boric oxide equivalent	24000
Germany, compounds	NA
Kazakhstan, unspecified	NA
Peru, crude borates	4000
Russia, datolite ore	40000
Turkey, refined borates	1100000
USA	40000

Source: *USGS, Mineral Commodity Summaries, 2020.*
(1)' World totals could not be calculated because production and reserves are not reported in a consistent manner by all countries.
xx*: Not applicable*

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

(In metric tonnes)

Country	2016	2017	2018
Turkey	2070257	2494627	2500000*
USA(a)	1300000*	1300000*	1300000*
Argentina	520000*	519000*	544400*
Kazakhstan	510000*	500000*	500000*
Chile	558854	607076	398411
Bolivia	199924	223515	232268
Peru	33792	-	100552
Russia	80000*	75000*	75000*
China(b)	80000*	70000*	70000*
Iran(c)	-	1150	1000*

Source: *BGS, World Mineral Production, 2014-18,*
a: Soblor used by producers, b: B_2O_3 equivalent.
**: Estimate, c: Years ended 20 March following that stated.*

Turkey

The first known instances of borate mining in Turkey date to Roman times, with borate mining continuing to this day. Approximately 73% of the world's boron reserves are in Turkey, with 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, were Bigadic (colemanite and ulexite), Emet (colemanite), Kestelek (colemanite, probertite, and ulexite) and Kirka (tincal). Production of refined borates has increased since 2008 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. Eti Maden projected a borate production capacity of 5.5 Mt with an anticipated sales income of $2.5 billion by 2023.

Argentina

Argentina was the third-ranked producer of boron minerals in South America in 2017. 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 in Brazil and, to a lesser degree, domestic consumers.

Borax Argentina S.A. (a subsidiary of Orocobre Ltd), 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. Borate production in 2017 was estimated to be 39,000 tonnes.

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 granular deca- and pentahydrate borax, technical-grade boric acid powder, and 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

The largest ulexite deposit in the world, Salar de Surire, was operated by Quiborax SA, a Government entity with reserves estimated to be 1.5 million metric tonnes (Mt). Almost all of the material mined at this location was exported in 2017. Chile also was the leading borate-compound producer in South America with production of 36,000 tonnes of boric acid in addition to 1,00,000 tonnes of borate-derived agrochemical products.

China

China has low-grade boron resources and since the demand for boron was expected to increase in China, imports from Chile, Russia, Turkey, and the United States also were 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 average about 8% B_2O_3 as opposed to the reserves from Turkey and the United States that average from 26% to 31% and 25% to 32% B_2O_3 respectively.

Serbia

Erin Ventures Inc. (Canada), initiated proceedings to begin borate mining in Piskanja, a mining region in Serbia approximately 250 km (155 miles) south of Belgrade. The deposit is primarily composed of colemanite and ulexite with estimated reserves of 11.8 Mt. Exploration began in early 2016 with two drill holes that indicated B_2O_3 content between 22% and 35% (Erin Ventures Inc., 2016). In 2017, Erin Ventures began the next phase of exploration with four drill holes to assess potential mineral body propagation.

FOREIGN TRADE

Exports

Exports of borax (total) decreased considerably by 25% to 2,360 tonnes in 2018-19 from 3,136 tonnes in the previous year. Exports of natural borate in 2018-19 increased manifold to 105 tonnes from 16 tonnes in the previous year. In 2018-19, exports of sodium borate were at 1,243 tonnes and other borates 1,012 tonnes. Exports of Borax (total) were mainly to Malaysia (29%), USA (21%), Nepal (8%), Italy (7%), Bangladesh (6%) and UAE (5%). Exports of boric acid decreased slightly by 4% to 1,321 tonnes in 2018-19 from 1,379 tonnes in the previous year. Exports were mainly to Thailand (14%), Nigeria (12%) and Nepal & Bangladesh (8% each) (Tables-4 to 9).

Imports

Imports of borax (total) increased marginally by 13% to 1,81,626 tonnes in 2018-19 from 1,60,135 tonnes in the previous year. Imports of natural borate also increased marginally by 16% to 85,217 tonnes as compared to 73,386 tonnes in the previous year. In 2018-19, imports of sodium borate were at 86,688 tonnes and other borates 9,722 tonnes. Borax (total) was mainly imported from Turkey (64%), USA (19%), Spain (6%), Bolivia (5%) and Malaysia (2%). Imports of boric acid decreased by 12% to 6,535 tonnes in 2018-19 from 7,412 tonnes in the previous year. Boric acid was imported mainly from Turkey (48%), USA (35%) and Singapore (11%). Import of boron was negligible in 2018-19 as compared to one tonne reported in the previous year (Tables-10 to 15).

Table – 4 : Exports of Boron (By Countries)

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**++**	**26**	**++**	**1971**
USA	++	26	++	1894
Singapore	-	-	++	49
UK	-	-	++	27
China	-	-	++	1

Figures rounded off

Table – 5 : Exports of Borax (By Countries)

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**3136**	**261796**	**2360**	**238104**
USA	401	63049	505	95100
Malaysia	1418	60207	678	30856
Italy	400	51026	158	23177
Bangladesh	105	15048	137	13829
UAE	24	3631	120	9459
Australia	70	13201	40	9440
Nepal	54	4083	179	8193
Poland	-	-	40	5974
Thailand	100	4312	100	4696
Oman	28	6065	20	4587
Other countries	535	41174	383	32792

Figures rounded off

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

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**16**	**561**	**105**	**1887**
Argentina	-	-	47	1503
Nepal	14	407	4	344
Bangladesh	-	-	54	35
UK	-	-	++	5
Bhutan	++	34	-	-
China	++	++	-	-
Rwanda	1	36	-	-
Saudi Arabia	++	++	-	-
Singapore	++	1	-	-
Sri Lanka	++	10	-	-
Other countries	1	72	-	-

Figures rounded off

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

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**2085**	**98830**	**1243**	**61645**
Malaysia	1418	60195	675	30697
Nepal	22	2163	154	6505
USA	99	13000	15	5195
Thailand	100	4312	100	4586
Myanmar	136	5592	88	3736
Angola	5	181	61	2781
UAE	1	67	75	2592
Saudi Arabia	40	1665	40	1813
Georgia	-	-	1	1168
Oman	-	-	1	505
Other countries	265	11654	33	2066

Figures rounded off

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

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1033**	**162406**	**1012**	**174572**
USA	302	50049	490	89905
Italy	400	51026	158	23177
Bangladesh	105	15004	81	13622
Australia	70	13050	40	9440
UAE	23	3564	45	6868
Poland	-	-	40	5974
Oman	28	6065	19	4082
Vietnam	3	1100	9	3544
France	20	3275	20	3271
Sri Lanka	10	6353	7	2963
Other countries	72	12919	103	11726

Figures rounded off

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

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1377**	**100729**	**1321**	**107106**
Nigeria	276	16393	160	14345
USA	78	12642	93	12459
Ethiopia	26	1802	97	8323
Thailand	++	60	189	8191
Nepal	75	6058	105	7775
Bangladesh	62	3191	110	5389
Syria	21	1429	68	5091
Uganda	30	2017	55	4643
Bhutan	31	2145	52	4019
Ghana	10	744	44	3747
Other countries	770	54248	348	33124

Figures rounded off

Table – 10 : Imports of Borax (By Countries)

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**160135**	**4753976**	**181626**	**5886239**
Turkey	106779	2888031	116714	3475577
USA	34705	1149618	34085	1254940
Spain	10078	354737	11144	446621
Bolivia	4120	57340	9742	158750
China	1274	122898	1439	143482
Malaysia	123	5244	3260	112745
Argentina	798	35621	2303	106053
UK	6	1756	544	45348
Singapore	-	-	1082	41335
Peru	856	47331	250	20401
Other countries	1396	91400	1063	80987

Figures rounded off

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

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**73386**	**1713685**	**85217**	**2206204**
Turkey	59978	1352874	66306	1713644
Spain	8669	291038	8829	323353
Bolivia	4120	57340	9742	158750
Argentina	80	3039	198	5868
Chile	27	491	142	4560
USA	-	-	++	16
Japan	++	38	++	13
Iran	482	8030	-	-
Russia	30	829	-	-
Italy	++	6	-	-

Figures rounded off

Table – 12 : Imports of Borax: Sodium Borates (By Countries)

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**76415**	**2486188**	**86688**	**3101908**
Turkey	42048	1346294	45318	1561371
USA	31833	1014287	32502	1170215
Spain	1241	56637	2315	123257
Malaysia	99	4302	3114	106431
Singapore	-	-	1080	40619
Argentina	607	24128	1273	39564
UK	++	4	454	15736
Netherlands	186	19222	138	15559
Indonesia	-	-	288	10083
China	23	630	105	6671
Other countries	378	20684	101	12402

Figures rounded off

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

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**10333**	**554103**	**9722**	**578126**
Turkey	4753	188863	5090	200562
China	1250	122268	1334	136811
USA	2871	135331	1583	84709
Argentina	111	8454	832	60621
UK	6	1752	90	29613
Austria	452	32023	262	20191
Peru	502	32364	194	15912
Italy	32	5910	33	6777
Malaysia	24	942	146	6314
Slovenia	147	6971	114	6131
Other countries	185	19225	44	10485

Figures rounded off

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

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**7412**	**304862**	**6535**	**284858**
Turkey	2969	123945	3151	139033
USA	3511	141362	2313	96156
Singapore	-	-	735	32140
Peru	832	32600	203	8211
China	100	6431	100	6802
Germany	++	378	12	1207
Netherlands	-	-	21	898
France	++	1	++	392
Canada	-	-	++	9
Japan	-	-	++	7
Other countries	++	145	++	3

Figures rounded off

Table – 15 : Imports of Boron
(By Countries)

Country	2017-18 (R)		2018-19 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1**	**7701**	**++**	**3317**
China	1	6210	++	1513
Canada	-	-	++	940
Belgium	++	622	++	301
UK	++	96	++	267
USA	++	643	++	182
Germany	++	14	++	95
Japan	++	116	++	19

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 refine and technologies and the continued increase in demand were expected to fuel growth in world production for the foreseeable future. In 2013, the European Union (EU) added borates to the Registration, Evaluation, Authorisation and Restrictions of Chemicals (REACH) Restricted Substances List, following an EU study that determined continuous exposure to humans may be harmful. The ruling required detergent makers to decrease their use of boron (Lismore, 2012). Consumption of boron-based fertilizers is expected to increase as the demand for food and biofuel crops is on the rise. Higher crop prices have enabled farmers to invest 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 2017.

Consumption of boron nitride is expected to increase owing 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 for a variety of emerging applications. Hexagonal boron nitride is used in producing ceramics, creating intermetallic composites, imparting thermal shock resistance, improving machinability and reducing friction.