Indian Minerals Yearbook 2017

(Part- III : Mineral Reviews)

56th Edition

BORON MINERALS

(FINAL RELEASE)

GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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March, 2018

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.

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 is not available.

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-2.

Turkey is the leading producer of borates accounting for 37% of total world production followed by USA (24%), Argentina, Chile & Kazakhastan (10% each) and Bolivia (4%) during 2016. Apart from these, substantial quantities of borates are also produced by Peru (Table-3).

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

(In '000 tonnes of boric oxide)

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

Source: *Mineral Commodity Summaries, 2018, USGS.*

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

(In '000 tonnes)

Country	2014	2015	2016
World Total (rounded)	**6389**	**6048**	**5363**
Argentina[e]	600	480	520
Bolivia	168	166	200
Chile	497	518	559
China[eb]	160	160	160
Kazakhstan[e]	30	500	510
Peru	240	663	34
Turkey	3143	2181	2000[e]
USA[e]	1300	1300	1300
Other countries	251	81	81

Source: *World Mineral Production, 2012-16, BGS.*
b: B_2O_3 equivalent.

FOREIGN TRADE

Exports

Exports of borax (total) increased to 2,480 tonnes in 2016-17 from 1,724 tonnes in the previous year. Exports of natural borate in 2016-17 decreased considerably to 65 tonnes as compared to previous year. In 2016-17, exports of sodium borate were 1,969 tonnes and other borates 446 tonnes. Exports of Borax (total) were mainly to Malaysia (31%), Indonesia (16%), Thailand (14%), Nepal (7%) and Italy (6%). Exports of boric acid increased to 1,872 tonnes in 2016-17 from 1,000 tonnes in the previous year. Exports were mainly to Iran, Nigeria, UAE and Thailand (Tables-4 to 9).

Imports

Imports of borax (total) decreased slightly by 3% to 1,29,407 tonnes in 2016-17 from 1,33,551 tonnes in the previous year. Imports in 2016-17 for natural borate also decreased slightly by 4% to 51,976 tonnes as compared to 53,973 tonnes in the previous year. In 2016-17, imports for sodium borate were 67,230 tonnes and other borates 10,201 tonnes. Borax (total) was mainly imported from Turkey, USA, Spain, China and Chile. Imports of boric acid substantially increased by 35% to 20,529 tonnes in 2016-17 from 15,183 tonnes in the previous year. Boric acid was imported mainly from USA (34%),Turkey (28%), Chile (22%) and Peru (15%). On the other hand, import of boron was only one tonne in 2016-17 as compared to negligible in the previous year (Tables-10 to 15).

Table – 4 : Exports of Boron (By Countries)

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**++**	**21**	**1**	**14**
Bangladesh	-	-	1	14
Singapore	++	14	-	-
Germany	++	7	-	-

Table – 5 : Exports of Borax (By Countries)

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1724**	**124645**	**2480**	**164054**
Malaysia	++	7	763	35635
USA	143	26291	98	21016
Italy	38	4316	140	15508
Indonesia	-	-	403	13661
Thailand	103	4284	350	13171
Bangladesh	317	20289	92	13157
Sri Lanka	31	9917	58	10286
Nepal	109	2452	185	10134
Oman	11	1913	40	6496
UAE	261	10818	134	4671
Other countries	711	44358	217	20319

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**141**	**1513**	**65**	**1329**
Nepal	61	437	13	798
UAE	4	87	52	432
Qatar	-	-	++	90
Baharain Is	++	3	++	7
Spain	-	-	++	2
Vietnam	25	546	-	-
Kenya	50	414	-	-
Rwanda	++	15	-	-
South Africa	1	8	-	-
USA	++	3	-	-

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1135**	**51516**	**1969**	**93325**
Malaysia	++	7	763	35635
Indonesia	-	-	403	13661
Thailand	61	2980	350	13032
Nepal	43	1715	165	8943
USA	14	4127	13	7182
Iran	312	13250	96	4397
Oman	11	1913	23	3791
UAE	255	10426	74	2653
Sri Lanka	21	707	42	1442
Myanmar	88	3893	20	865
Other countries	330	12498	20	1724

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**448**	**71616**	**446**	**69400**
Italy	38	4316	140	15508
USA	129	22161	85	13834
Bangladesh	93	12649	92	13110
Sri Lanka	10	9210	16	8844
France	10	1818	20	3368
Australia	62	9832	20	3124
Germany	11	3883	12	2761
Oman	-	-	17	2705
UAE	2	305	8	1586
South Africa	7	681	6	902
Other countries	86	6761	30	3658

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**1000**	**81553**	**1872**	**116916**
Iran	351	19912	555	30841
Nigeria	200	17138	388	22346
UAE	26	2200	157	9474
USA	45	6853	45	7387
Thailand	43	2095	126	5822
Nepal	38	3643	52	5319
Uganda	6	609	54	4295
Indonesia	-	-	58	2805
Saudi Arabia	28	2366	35	2802
Cameroon	18	1958	24	2713
Other countries	245	24779	378	23112

Table – 10: Imports of Borax (By Countries)

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**133551**	**4429455**	**129407**	**4359797**
Turkey	86031	2724129	84318	2594725
USA	25145	956583	30315	1126708
Spain	9344	329496	8859	308544
China	1349	116456	1309	119275
Peru	624	22125	681	32088
Austria	731	46126	436	30355
Chile	1053	18042	1566	27774
Malaysia	637	25166	564	22782
UK	14	12197	37	21433
Netherlands	106	11180	184	18680
Other countries	8517	167955	1138	57433

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**53973**	**1413805**	**51976**	**1400792**
Turkey	37890	1054010	42328	1115646
Spain	6968	215390	7632	246775
Chile	1053	18042	1566	27774
Iran	197	4025	379	8844
UAE	-	-	50	862
Argentina	112	3557	20	791
Japan	++	27	1	100
Bolivia	7753	118754	-	-

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**75974**	**2739111**	**67230**	**2417843**
Turkey	47812	1658259	37671	1322918
USA	24382	896234	26798	959888
Spain	2313	110821	1227	61520
Peru	483	16529	487	19339
Netherlands	106	11180	174	18360
Malaysia	516	18703	456	16121
Korea, Rep. of	-	-	237	8281
Argentina	213	16592	162	6467
Germany	1	2303	1	2772
China	5	1794	9	1299
Other countries	143	6696	8	878

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**3604**	**276539**	**10201**	**541162**
USA	763	60349	3517	166820
Turkey	329	11860	4319	156161
China	1344	114662	1300	117976
Austria	731	46126	436	30355
UK	14	12186	37	21388
Peru	141	5596	194	12749
Argentina	-	-	108	8858
Malaysia	121	6463	108	6661
Japan	1	667	7	5581
Slovenia	38	1818	91	4654
Other countries	122	16812	84	9959

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

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**15183**	**732378**	**20529**	**897345**
USA	6898	346192	6936	301863
Turkey	6302	291823	5675	264992
Chile	77	3573	4448	182882
Peru	1575	73404	3098	128755
Russia	220	9795	120	5447
Singapore	-	-	84	3946
China	90	6114	60	3901
Spain	++	17	105	3586
Germany	++	325	++	1306
Italy	-	-	2	431
Other countries	21	1135	1	236

Table – 15: Imports of Boron (By Countries)

Country	2015-16 (R)		2016-17 (P)	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**++**	**1280**	**1**	**9076**
China	++	475	1	6500
USA	++	675	++	1986
Belgium	-	-	++	264
Canada	-	-	++	186
Japan	++	78	++	101
UK	++	48	++	37
Germany	++	4	++	2

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.