## REVIEW ARTICLE

# MEDICINAL, COSMETIC, CHEMICAL AND OTHER APPLICATIONS OF BORATES

Sadia Hafeez Kazi*, Syeda Ayesha Ahmed un Nabi

Department of Pharmaceutics, Baqai Institute of Pharmaceutical Sciences,
Baqai Medical University, Karachi, Pakistan
Received: March 9, 2018 Accepted: October 17, 2018

**ABSTRACT**
Boron and its related compounds are found in abundance in nature such as soil, water, and plants. Use of borates dates back to the time of Babylonians and Egyptians, some 4000 years ago, for gold refining and mummifying the dead. It was later discovered as a useful laboratory and industrial agent along with an effective antiseptic and insecticidal compound. In combination with other compounds, boron complexes showed a positive effect as an anticancer agent. Currently, borates are extensively employed in the field of medicine, dentistry, cosmetology, nuclear, aeronautical fuels, weaponry, agricultural, chemicals, etc. Moreover, they are also used in industrial processes as abrasives, refractories, flame retardants, glazes, frits, enamels, and metallurgy. The various characteristics of borates including its application are discussed and reviewed in this article, which may be beneficial for researchers in the development of various scientific and technological fields.

**Keywords:** Borates, borax, boric acid, boron.

## 1. INTRODUCTION

### 1.1. Medicine, Dentistry, and Cosmetology

Boric acid and its derivatives find a wide variety of applications in the field of medicine, dentistry, and cosmetology[1,2]. Sodium borate and boric acid have been used as a mild antiseptic to inhibit gram-negative bacteria and as an eyewash. Borax and some of its ores are very effective against some parasites[1,3] while boron compounds are known to inhibit tumor growth in cancer patients[1,4-7] as well as reduce cholesterol and other harmful proteins[8]. The corticosteroids, which have been used in arthritis therapy and in the synthesis of vitamin D, are also prepared by potassium borohydride ($KBH_4$)[9].

Borax and sodium perborate are useful components in the field of dentistry. They are used in dental cements and occasionally added to the powder of glass-ionomer cement[1,10]. As a bleaching agent, sodium perborate has been used for intracranial bleaching of teeth and showed no effect on the bond strength and hardness on denture liners[1,11]. However, an interesting clinical trial has been performed by Moffa et al.,[12] that use of sodium perborate and chlorohexidine with a toothbrush was able to remove the biofilms of relined denture and no roughness of teeth has been observed after 15 days of use. Similarly, sodium borohydride ($NaBH_4$) is also widely used in the preparation of hormones, face creams, lotions, dusting powders, ointments, hair preparations, mouthwashes, and emulsifier in medical and cosmetic formulations[1].

### 1.2. Nuclear Applications

Boron is considered as the most effective material for shielding neutrons produced during nuclear reactions. The $^{10}B$ isotope of boron obtained by ion exchange or fractional distillation of boron trifluoride ($BF_3$) or its dimethyl ether complex [$(CH_3)_2O.BF_3$] possesses the highest neutron-capture capability. Boron carbide is also widely used as neutron absorbing and shielding material which makes the handling, transportation, and storage of spent fuel elements possible. Similarly, the addition of borates to concrete or structural ceramics also increases its neutron absorbing ability [1,13-17].

* Corresponding Author Email: dia_kazi@hotmail.com

### 1.3. Chemical Industry

The borate derivatives especially borax and sodium perborate find a wide range of cleaning or bleaching effect for a variety of materials. They are used in emulsification of oil and greases and reduction of surface tension of water for purpose of loosening dirt particles due to its mild alkalinity. As a cleansing agent, borax gives a strong but gentle action on many types of fabrics, surfaces, and contaminants in addition to its many other cleaning applications when combined with surface active agents, abrasives or soap bars[1,18].

The crystallized, centrifuged and dried sodium perborate obtained after reaction of borax with sodium hydroxide and hydrogen peroxide is stabilized with magnesium sulfate and silicates[1]. As it is more powerful than chlorine-type bleaches, therefore, is widely used as laundry cleanser, act as both mild alkali and a controlled oxidizing agent for loosening dirt and gently remove stains or contaminants from clothes[1,19]. Both mono and tetrahydrate forms of sodium perborate have good storage stability and are also used for pulp-mill[20], textile bleaching[21,22], dye oxidation[23], tooth powders[24], laundry bleaches[25], dishwashing powders[26,27], denture[12], household surface, and other special-purpose cleaners[1].

### 1.4. Agriculture

The agricultural applications of borates and its derivatives are well known for plant growth[1,28,29]. The exact function of boron in plants being unclear but still, it is related to translocation or control of the amount of various organic compounds. In addition to this, cell wall growth[30] increased the effect of sugars on the hormone action in plants[31], the amount of photosynthesis, the rate of $CO_2$ absorption from air and growth of plant roots are some of the other important uses of boron[1,32,33]. The application of boron fertilizer is preferred for plants especially in dormant periods[1,34,35].

### 1.5. Abrasives and Refractories

The applications of boride compounds as abrasives and refractories are well known due to their hard texture and high thermal and electrical conductivity[36,37]. Boron carbide ($B_4C$) is used as a polishing agent for sandblasting nozzles and in nuclear shielding[38-40]. Similarly, boron carbide composite with fiberglass combination can be used to stop a 30 caliber bullet at a point-blank range and has been employed for the manufacture of seats in AH–10 Cobra attack helicopter along with bulletproof jackets[41,42]. Boron composite such as silicon boron carbonitride ($Si_3BC_{4.3}N_2$) is found to have an extraordinarily high thermal stability[43-46]. Boron nitride (BN) has good machinability, high thermal conductivity and excellent resistance to thermal shock and is a low-density electrical insulator[47]. Its solid, powder or aerosol forms are widely used for making crucibles, molten metal nozzles, and lubricants[38,48]. The borides of chromium, aluminum, hafnium, titanium and zirconium gain high popularity for use due to hardness, good strength, wear resistance, electrical conductivity, and protection against chemical attack[47,49,50].

### 1.6. Flame Retardants

The application of boric acid, borax, and pentahydrate are also observed in preparing inexpensive cellulose insulation material by treating cellulose with a boric acid solution, which after drying becomes reasonably good fire resistant, toxic to bacteria and unbearable for rats, mice and insects[51,52]. This reaction of boric acid with hydroxyl groups of cellulose results in the formation of very thin and stable film[53]. The zinc borate derivative, formed after reaction of zinc oxide and boric acid is found to have greater flame retardancy than borates used alone and it only promotes char with inhibition of combustible material[54,55]. Aluminum trihydrate if added to zinc borate may also act as a synergistic mixture in reducing fire's smoke[56,57].

### 1.7. Fuels

Boron and its hydrides are also considered as a fuel for space or aircraft and drones due to the presence of highest heat of combustion per unit weight of all elements i.e. 25,120 Btu/lb but the production of harmful end products and high cost restrict its commercial use. Sodium borohydride has been used

in jet bomber fuel by the US Navy for its highly effective antioxidant activity for hydrocarbon fuels[58,59]. Boron in combination with polytetrafluoroethylene is employed as fuel for hybrid rockets[60]. The use of certain organoboron compounds in the sterilization of hydrocarbon fuel storage systems to reduce corrosion and prevention of growth and clogging filters by microorganisms has also been reported. Some other applications of borates in fuel science include the use of boron trichloride or fluoride as a catalyst in petroleum refining and boron-nickel catalysts for converting carbon monoxide to fuel[61].

### 1.8. Glazes, Frits and Enamels

The use of borates in the production of glazes and frits to give color and texture as well as heat, chemical and wear resistance to appliances, ceramics, and tiles is considered as one of the earliest use of borax[62]. The presence of borax helps to produce smooth, hard, resistant, free of blemishes and craze-free ceramic surfaces[63]. Salt glazing can also be achieved by adding borax to salt as well as an increase in craze resistance in earthenware glazes in amounts less than 10% is another property of boric oxide[64]. The commercial tableware glazing is also replaced by high-borate, non-lead mixture due to lead poisoning which was formerly glazed with lead oxide-boric oxide frits[65]. A highly reactive borosilicate glazing may also be applied to wall and floor tiles for enhancing decoration, and molten borax to metal pipes and vessels for protection against corrosion[66,67].

### 1.9. Metallurgy

In case of preparing metal alloys of steel, the addition of 0.001–0.003% boron reduces the amount of nickel, chromium or molybdenum required in many alloys[68]. The alloys of boron are harder and stronger than the parent metal due to its ability to locate itself in the interstitial spaces. Sometimes boron also causes poor surface characteristics, less heat tolerance, and brittleness to metal. Another important application of boron alloys with aluminum and titanium is smelting of grain refiners to form a fine and uniform structure[69]. Borates are also applied in gold refining and assay[70] while in nuclear plants neutron instance has to be monitored and controlled. Borates with stainless steel are employed because of their neutron absorbing property[71,72].

## 2. CONCLUSION

Borates are a natural form of boron which is used extensively in the field of science and technology. Researchers have been using this compound for centuries in various fields for human and animal consumption. For a quick view sodium borate, sodium perborate, calcium perborate, magnesium perborate, disodium octaborate, copper borate, zinc borate, phenylmercuric borate, and potassium/sodium borohydride are utilized for soldering metals, bleaching and denture making, metallurgical extraction etc. It is also used as an antiseptic, fungicidal, preservative, fire retardant and a reducing agent in chemical reactions.

## FUNDING

None mentioned.

## CONFLICT OF INTEREST

The author declares no conflict of interest.

## REFERENCES

1. Ahmad I, Ahmed S, Sheraz MA, Vaid FHM. Borates: Chemical, Pharmaceutical and Pharmacological Aspects, 1st ed., Nova Science Publishers, Inc., New York, USA, 2011.
2. Ince S, Arslan-Acaroz D. An update on health effects of metalloid trace element: Boron. Aperito J Drug Design Pharmacol. 2015;2:1-6.
3. Kannan C, Aditi P, Zwanenburg B. Quenchings the action of germination stimulants using borax and thiourea, a new method for controlling parasitic weeds: A proof of concept. Crop Protection. 2015;70:92-98.
4. Muezzinoglu T, Korkmaz M, Nese N, Bakirdere S, Arslan Y, Ataman OY, Lekili M. Prevalence of prostate cancer in high boronexposed population: a community-based study. Biol Trace Elem Res. 2011;144:49-57.
5. Ince S, Kucukkurt I, Cigerci IH The effects of dietary boric acid and borax supplementation

on lipid peroxidation, antioxidant activity, and DNA damage in rats. J Trace Elem Med Biol. 2010;24:161-164.
6. Gregoire V, Begg AC, Huiskamp R, Verrijk R, Bartelink H. Selectivity of boron carriers for boron neutron capture therapy: pharmacological studies with borocaptate sodium, L-bronophenylalanine and boric acid in murinetumors. Radiother Oncol. 1993;27: 46-54.
7. Primus FJ, Pak RH, Richard-Dickson KJ, Szalai G, Bolen JLJr, Kane RR, Hawthorne MF. Bispecific antibody mediated targeting of nido-carboranes to human colon carcinoma cells. Bioconjug Chem.1996;7:532-535.
8. Scorei R, Popa R. Boron-containing compounds as preventive and chemotherapeutic agents for cancer. Anti-Cancer Agent Med Chem. 2010;10:346-351.
9. Fujii S, Masuno H, Taoda Y, Kano A, Wongmayura A, Nakabayashi M, Ito N, Shimizu M, Kawachi E, Hirano T, Endo Y. Boron cluster-based development of potent nonsecosteroidal vitamin D receptor ligands: direct observation of hydrophobic interaction between protein surface and carborane. J Am Chem Soc. 2011;133:20933-20941.
10. Shen L, Coughlan A, Towler M, Hall M. Degradable borate glass polyalkenoate cements. J Mat Sci. 2014;25:965-973.
11. de Souza B, Silva Araujo C, Soares CJ, Faria-e-Silva AL. Effect of dentin pretreatment on bond strength stability of self-etching and etch-and-rinse adhesives to intracoronally bleached dentin. J Adhesive Dent. 2016;18:349-354.
12. Moffa EB, Izumida FE, Jorge JH, Mussi MC, Siqueira WL, Giampaolo ET. Effectiveness of chemical disinfection on biofilms of relined dentures: A randomized clinical trial. Am J Dent. 2016;29:15-29.
13. Hora H, Miley GH, Ghoranneviss M, Malekynia B, Azizi N, He XT. Fusion energy without radioactivity: laser ignition of solid hydrogen–boron (11) fuel. Ener Environ Sci. 2010;3:478-485.
14. Nevins WM, Swain R. The thermonuclear fusion rate coefficient for p - $^{10}$B reactions. Nucl Fusion. 2000;40:865-870.
15. Picciotto A, Margarone D, Velyhan A, Bellutti P, Krasa J, Szydlowsky A, Bertuccio G, Shi Y, Mangione A, Prokupek J, Malinowska A. Boron-proton nuclear-fusion enhancement induced in boron-doped silicon targets by low-contrast pulsed laser. Phys Rev X. 2014;4:310-330.
16. Taheri A, Pazirandeh A. Measurements of the thermal neutron flux for an accelerator-based photoneutron source. Aust Phys Engr Sci Med. 2016;39:857-862.
17. Zarma SF, Mirea DA, Busca I, Porschianu MN, Verga N. Implementing BNCT through the use of an electron accelerator. Rom Rep Phys. 2014;66:182-191.
18. Carretti E, Natali I, Matarrese C, Bracco P, Weiss RG, Baglioni P, Salvini A, Dei L. A new family of high viscosity polymeric dispersions for cleaning easel paintings. J Cul Heritage. 2010;11:373-380.
19. Lee S, Kessler S, Forberich O, Buchwar C, Greenspan DC. Cosmetic, personal care, cleaning agent, and nutritional supplement compositions and methods of making and using same. US Patent 7250174, 2007.
20. Leduc C, Sain MM, Daneault C. Use of new oxidizing agents (peroxide-activated peroxide-perborate) for the bleaching of mechanical pulp. Pulp Pap Canada. 2001;102:34-38.
21. Hage R, Lienke A. Applications of transition-metal catalysts to textile and wood-pulp bleaching. Angew Chem Int Ed Engl. 2006;45:206-222.
22. El Shafie A, Fouda MM, Hashem M. One-step process for bio-scouring and peracetic acid bleaching of cotton fabric. Carbohydr Polym. 2009;78:302-308.
23. Lim MI, Popp M, Pan YG. Oxidative hair dye compositions and methods containing 1-(4-aminophenyl)-2-pyrrolidinemethanols. US Patent 5993491, 1999.
24. Smigel I, Raziq SI. Powder composition for forming a mouthwash. US Patent 4925655, 1990.
25. Milne NJ. Oxygen bleaching systems in domestic laundry. J Surf Deterg. 1998;1:253-261.

26. Burg B, Haerer J, Jeschke P, Buchmeier W, Blum H, Nitsch C, Voelkel HJ, Speckmann HD. Mildly alkaline dishwashing detergents. US Patent 5898025, 1999.
27. Levin NA, Kaplan LL. Enzyme-containing denture cleanser tablet. US Patent 3962107, 1976.
28. Yermiyahu U, Ben-Gal A, Keren R, Reid RJ. Combined effect of salinity and excess boron on plant growth and yield. Plant Soil. 2008;304:73-87.
29. Blevins DG, Lukaszewski KM. Boron in plant structure and function. Ann Rev Plant Biol. 1998;49:481-500.
30. Matoh T. Boron in plant cell walls. Plant Soil. 1997;193:59-70.
31. Devirian TA, Volpe SL. The physiological effects of dietary boron. Crit Rev Food Sci Nutr. 2003;43:219-231.
32. Han S, Chen LS, Jiang HX, Smith BR, Yang LT, Xie CY. Boron deficiency decreases growth and photosynthesis, and increases starch and hexoses in leaves of citrus seedlings. J Plant Physiol. 2008;165:1331-1341.
33. Li M, Zhao Z, Zhang Z, Zhang W, Zhou J, Xu F, Liu X. Effect of boron deficiency on anatomical structure and chemical composition of petioles and photosynthesis of leaves in cotton (*Gossypium hirsutum L.*). Sci Rep. 2017;7: 4420-4429.
34. Xie L, Liu M, Ni B, Zhang X, Wang Y. Slow-release nitrogen and boron fertilizer from a functional superabsorbent formulation based on wheat straw and attapulgite. Chem Eng J. 2011;167:342-348.
35. Roux P, Turpault MP, Kirchen G, Redon PO, Lemarchand D. Boron dissolved and dust atmospheric inputs to a forest ecosystem (Northeastern France). Environ Sci Technol. 2017;51:14038-14046.
36. Chen ZQ, Peng YS, Hu M, Li CM, Luo YT. Elasticity, hardness, and thermal properties of ZrBn (n=1, 2, 12). Ceram Int. 2016;42: 6624-6631.
37. Drobyaz E, Zimoglyadova TA, Gromov V. Electron-beam surfacing wear-resistant coatings, reinforced refractory metal's borides. Appl Mech Mater. 2015;698:419-423.
38. Sychuk V, Zabolotnyi O, McMillan A. Developing new design and investigating porous nozzles for abrasive jet machine. Powder Metall Met Ceram. 2015;53:600-605.
39. Akkas A, Tugrul A, Addemir O, Marsoglu M, Agacan B, Buyuk B. Radiation shielding effect of boron carbide aluminum metal matrix composite. Acta Phys Pol A. 2015;4:947-949.
40. Abdullah Y, Yusof MR, Kamarudin N, Paulus WS, Mustaffa R, Zali NM, Shamsudin R. Fabrication and characterisation of aluminium boron carbide composites for neutron shielding. J Sains Nukl Malays. 2017;24:71-80.
41. Marsh G. Ballistic composites – protecting the protectors. Reinf Plast. 2017;61:96-99.
42. Boussu F. The use of warp interlock fabric inside textile composite protection against ballistic impact. Text Res J. 2011;81:344-354.
43. Liang B, Yang ZH, Jia DC, Rao JC, Yu D-L, Tian YJ, Li Q, Miao Y, Zhu QS, Zhou Y. Amorphous silicoboron carbonitride monoliths resistant to flowing air up to 1800°C. Corros Sci. 2016;109:162-173.
44. Liang B, Jia D, Miao Y, Zhu Q, Liao X, Yang Z, Zhou Y. High temperature oxidation kinetics of amorphous silicoboron carbonitride monoliths and silica scale growth mechanisms determined by SIMS. Corros Sci. 2017;122:100-107.
45. Bejar MA, Moreno E. Abrasive wear resistance of boronized carbon and low-alloy steels. J Mat Proc Tech. 2006;173:352-358.
46. Navas C, Colaco R, De Damborenea J, Vilar R. Abrasive wear behaviour of laser clad and flame sprayed-melted NiCrBSi coatings. Surf Coat Tech. 2006;200:6854-6862.
47. Kemaloglu S, Ozkoc G, Aytac A. Properties of thermally conductive micro and nano size boron nitride reinforced silicon rubber composites. Thermochim Acta. 2010;499:40-47.
48. Chattopadhyay AK, Hintermann HE. On brazing of cubic boron nitride abrasive crystals to steel substrate with alloys containing Cr or Ti. J Mat Sci. 1993;28:5887-5893.
49. Kumar S, Dilba S, Kalsi NS. Study the

performance of solid lubricants during machining of variable hardened AISI 4340 steel using grey-fuzzy approach. Int J Curr Trends Sci Technol. 2017;7:20367-20380.
50. Fahrenholtz WG, Hilmas GE, Talmy IG, Zaykoski JA. Refractory diborides of zirconium and hafnium. J Am Ceramic Soc. 2007;90: 1347-1364.
51. Wicklein B, Kocjan D, Carosio F, Camino G, Bergstrom L. Tuning the nanocellulose borate interaction to achieve highly flame retardant hybrid materials. Chem Mater. 2016;28: 1985-1989.
52. Bar M, Alagirusamy R, Das A. Flame retardant polymer composites. Fibers Polym. 2015;16: 705-717.
53. Lopez Hurtado P, Rouilly A, Vandenbossche V, Raynaud C. A review on the properties of cellulose fibre insulation. Build Environ. 2016;96:170-177.
54. Ren Y, Wang Y, Wang L, Liu T. Evaluation of intumescent fire retardants and synergistic agents for use in wood flour/recycled polypropylene composites. Constr Build Mater. 2015;76: 273-278.
55. Feng C, Zhang Y, Liang D, Liu S, Chi Z, Xu J. Influence of zinc borate on the flame retardancy and thermal stability of intumescent flame retardant polypropylene composites. J Anal Appl Pyrolysis. 2015;115:224-232.
56. Yang S, Lv G, Liu Y, Wang Q. Synergism of polysiloxane and zinc borate flame retardant polycarbonate. Polym Degrad Stab. 2013;98:2795-2800.
57. Dogan M, Yilmaz A, Bayramli E. Synergistic effect of boron containing substances on flame retardancy and thermal stability of intumescent polypropylene composites. Polym Degrad Stab. 2010;95:2584-2588.
58. Kim K, Kim T, Lee K, Kwon S. Fuel cell system with sodium borohydride as hydrogen source for unmanned aerial vehicles. J Power Sources. 2011;196:9069-9075.
59. Kim H, Oh TH, Kwon S. Simple catalyst bed sizing of a NaBH4 hydrogen generator with fast startup for small unmanned aerial vehicles. Int J Hydrog Energy. 2016;41:1018-1026.
60. Jr TLC, Risha GA, Yetter RA, Roberts CW, Young G. Boron and polytetrafluoroethylene as a fuel composition for hybrid rocket applications. J Propuls Power. 2015;31:373-385.
61. Liu L, Hong L. Ceria-supported nickel borate as a sulfur-tolerant catalyst for autothermal reforming of a proxy jet fuel. Catal Today. 2016;263:52-60.
62. Pradell T, Molera J, Smith AD, Tite MS. The invention of lustre: Iraq 9th and 10th centuries AD. J Archaeol Sci. 2008;35:1201-1215.
63. Casasola R, Rincon JM, Romero M. Glass-ceramic glazes for ceramic tiles: a review. J Mater Sci. 2012;47:553-582.
64. Bakil SNA, Hussin R, Aramjat AB. Influent of borax decahydrate composition as additional flux into stoneware bodies. IOP Conf Ser Mater Sci Eng. 2017;226:012165.
65. Lezhnina MM, Katker H, Kaiser M, Stegemann L, Voss E, Resch-Genger U, Strassert C, Kynast U. Chemical behavior and spectroscopic properties of rare earth borates in glazes. J Lumin. 2016;170:387-394.
66. Fernandes FAP, Gallego J, Picon CA, Tremiliosi Filho G, Casteletti LC. Wear and corrosion of niobium carbide coated AISI 52100 bearing steel. Surf Coat Technol. 2015;279:112-117.
67. Sista V, Kahvecioglu O, Eryilmaz OL, Erdemir A, Timur S. Electrochemical boriding and characterization of AISI D2 tool steel. Thin Solid Films. 2011;520:1582-1588.
68. Conrad HA, McGuire MR, Zhou T, Ibrahim Coskun M, Golden TD. Improved corrosion resistant properties of electrochemically deposited zinc-nickel alloys utilizing a borate electrolytic alkaline solution. Surf Coat Technol. 2015;272:50-57.
69. Garrett DE. Uses of Borates: Metallurgy. In: Borates: Handbook of Deposits, Processing, Properties, and Use, Academic Press, London, UK, 1998; p. 424.
70. Method of Gold Extraction using Borax-Small Scale Miners No Mercury. Mineral Processing & Metallurgy. Available at https://www.911metallurgist.com/blog/mercury-

free-gravity-borax-method-gbm. (Last accessed on October 2018).
71. Kumar GR, Ram GDJ, Rao SRK. Microstructure and mechanical properties of borated stainless steel (304B) GTA and SMA welds. Metall Ital. 2015;107:47-52.
72. Shanmugarajan B, Chary N, Padmanabham G, Arivazhagan B, Albert S, A. K. B. Studies on autogenous laser welding of type 304B4 borated stainless steel. Opt Lasers Eng. 2013;51: 1272-1277.