REVIEW ARTICLE

MEDICINAL, COSMETIC, CHEMICAL AND OTHER APPLICATIONS OF BORATES

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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].

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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.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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