"Science Stays True Here"
Biological and Chemical Research (ISSN 2312-0088), Vol.6, 150-154 | Science Signpost Publishing

Comparing the Performances of Aqueous Solution of Boric Acid/Borax and Powder Boric Acid/Borax in Corrugated Board Production Process

Aysun Altan, Erdal Akıncı, Meral Arca
Caran Kimya San. Tic. ve Ltd. Şti., 35060, İzmir, Turkey.

Received: May 16, 2019 / Accepted: June 15, 2019 / Published: September 25, 2019

Abstract: Boric acid and sodium borates (borax) are essential constituents of the starch adhesives used in corrugated board systems. They modify the physical and chemical properties of the adhesive and hence provide the operation of the corrugated board production line efficiently. [1]
Boric acid/borax holds potential risks to human health. In corrugated board, consumer exposure to boric acid/borax is not concerned since the starch adhesive containing boric acid/borax stays between the paper layers of corrugated board and the consumer does not get into contact with it. However, occupational exposure to boric acid/borax is a critical issue and occurs mainly through inhalation. The effects following the inhalation of the dust containing boric acid/borax are considered to be nasal and eye irritation, throat irritation, cough and breathlessness. Exposure to boric acid/borax may have adverse effect on fertility and be harmful for unborn child. [2] Due to their hazardous effects on human health, the alternatives of boric acid/borax are in search. However, in corrugated board adhesives, there is no alternative technology commercially available for now. [1]
The preparation of aqueous solution of boric acid/ borax diminishes the health hazards caused by inhalation of powder form of it. However, the water solubility of boric acid/ borax is about 4 % at 20°C which is a very low concentration to be used instead of powder boric acid/ borax in corrugated board production. [3] In this study, we developed a technique to prepare the aqueous solution of boric acid/borax with 25,7 % of boric acid and borax content. When the aqueous solution of boric acid/borax was used in corrugated board production line instead of powder boric acid/borax, it performed well concerning the quality of starch adhesive and the efficiency of the production line. [1]

Key words: borax solution, starch adhesive, corrugated board.

1. Introduction

The starch adhesives used in corrugated board systems are mainly composed of water, starch, sodium hydroxide, borax or boric acid and other additives such as preservatives, bond enhancers, defoamers etc. [1]

Borates in water dissociate as meta-borates and boric acid (Eq.1-3). Boric acid in water is in equilibrium with borate anion (Eq.3). The most important parameter that determines the fraction of borate anion in solution is pH of the solution. As the pH of the solution increases borate anion becomes more dominant in the medium. [3]

$$B_4O_7^{2-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow HB_4O_7^{-}{}_{(aq)} + OH^-{}_{(aq)} \quad (1)$$

$$B_4O_7^{2-}{}_{(aq)} + 5H_2O_{(l)} + 2H^+{}_{(aq)} \leftrightarrow 4H_3BO_3{}_{(aq)} \quad (2)$$

$$B(OH)_3{}_{(aq)} + H_2O_{(l)} \leftrightarrow B(OH)_4^-{}_{(aq)} + H^+{}_{(aq)} \quad (3)$$

In starch based adhesives, borate ions react with starch and form inter-chain linkages (Figure 1). The starch polymer turns into more highly branched chain polymer with higher molecular weight due to formation of inter-chain linkages. [1], [4], [5]

Corresponding author: Aysun Altan, E-mail: aysunaltan@carankimya.com

The inter-chain linked starch gives the required viscosity and structure to the adhesive. Film forming and flow properties, water holding capability of adhesive is improved by the formation of linkages between starch molecules and borate anion. These interactions helps the adjustment of the temperature sensitivity of the adhesive to the appropriate temperature on the corrugating production line. [1]

Lately, the impact of boric acid or sodium salts of boron (primarily borax, or disodium tetraborate decahydrate) used in the production of corrugated board on health and safety of humans as the consumers and the workers at the corrugated production line is being questioned. The consumers of corrugated board are not exposed to borates since the borate containing adhesive stays between the layers and borates do not migrate between the layers. Occupational exposure to boric acid/borax in corrugated board production facilities occurs during loading the boric acid/borax powders in to the starch adhesive batches. [2]

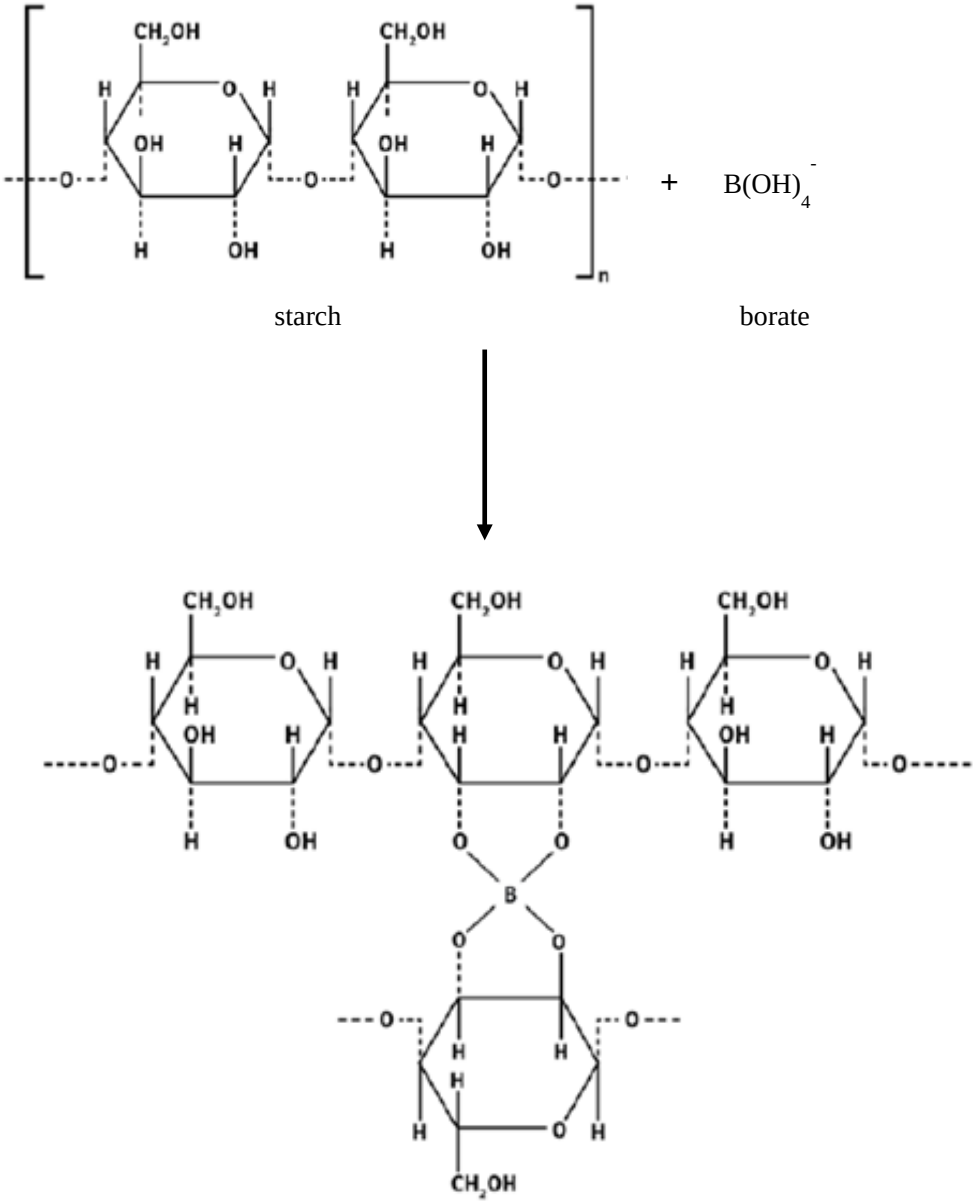

Figure1: Reaction of starch with borate anion.

In case of exposure, the effects of boric acid and borates on environmental and human health and safety is studied and reported. According to HERA 2005, Transitional Annex XV Report 2009, The EFSA Journal (2013) 11(10): 3407, 1-52, The EFSA Journal (2004), 80, 1-22, SCCS/1249/09.1-28, Directive 98/8/ EC (2009) boron is an inorganic element and does not biodegrade and is not subjected to hydrolysis or photochemical degradation and measured bioconcentration factors indicate no potential for bioaccumulation (B) of boron. Boric acid/ borates fulfill the criteria for toxicity (T) and they are classified as Repr. 1B, H360 DF (May damage fertility. May damage the unborned child). Since the criteria for persistency are not relevant for inorganic substances boric acid/borates do not fulfill the criteria for chemical persistence, bioaccumulation, toxicity (PBT) or very persistent and very bioaccumulative (vPvB). [2]

Boric acid and borax are reported as eye and respiratory tract irritants. Due to the occupational activities, inhalation of the dust sourcing from powders which contains boric acid or borax results in nasal and eye irritation, throat irritations, cough and breathlessness. Based on the occupational data, no observed effect concentration (NOEC) value of 0, 8 mg B/m^3 was obtained. The higher levels of exposure through inhalation may cause sneezing, nose bleeds, phlegm production and broncho-constriction (ECHA/ transitional annex XV report (2009a)). [2]

Low NOEC values for inhalation of boric acid/borax indicates that the usage of powder form of boric acid/borax in corrugated board adhesives should be abandoned. However, there is no alternative technology available commercially to replace boric acid/borax in corrugated board adhesives. In this situation, the most reasonable way of adding boron compounds into adhesive is in the form of aqueous solution since aqueous solution of boric acid/ borax diminishes the health hazards caused by inhalation of powder form of it. [2]

The solubility of boric acid/ borax in water is around 4 % at 20 °C. [3] The total amount of water can be present in a corrugated board adhesive has an upper limit. Water content of aqueous solution of boric acid/ borax at 4% concentration exceeds the acceptable water content limits to be used in corrugated board adhesive. [1], [6] The boron containing aqueous solutions at this concentration cannot be used in corrugated board adhesives due to high content of water. For all these reasons, concentration of boron containing solutions at room temperature should be increased.

In literature, there are studies which focus on dissolving boric acid or borax in water in the presence of amines or a polyhydroxyorganic compound. In these studies either boric acid or borax is dissolved in the presence of either an amine or a polyhydroxyorganic compound. [6]

In our study, boron containing compounds are dissolved in water in the presence of polyhydroxyorganic compound. Boric acid and borax are used together at an optimum ratio as boron containing compounds in order to get higher boron content in the solution.

2. Materials and Methods

The solution is prepared with boric acid, borax, a polyhydroxyorganic compound and water at 25 °C. The stability of solution was followed visually at 25 °C and 4 °C and monitored by measuring the solid content of the solution with Sartorious MA 35.

The performance of aqueous solution of boric acid and borax in starch adhesive was tested in production batch size by one of our customer which is a corrugated board manufacturer. The amount of boric acid and borax containing solution which required to replace the powder borax in the adhesive

was determined according to the viscosity and gel point of the adhesive. Viscosity of the adhesive was measured with Ford Cup4 in terms of seconds. Gel point of the starch adhesives was defined as the temperature at which starch gelatinizes.

3. Results and Discussion

A clear solution was obtained when boric acid and borax was dissolved in water in the presence of polyhydroxyorganic compound. The solid content of the solution was measured as 25, 4 %. Boron and water content of the prepared solution were calculated as 3, 57 % and 74, 6 % respectively.

Stability of the solution at 25 °C was followed for one month. During this period, the solution stayed clear; turbidity or crystals were not observed. The values obtained from the solid content measurements were between 25, 39 - 25, 43% which is checked weekly. These values assures the stability of the solution at 25 °C.

When the solution was stored at 4 °C, after two days, some crystals were observed at the bottom and on the walls of the sample container. The solid content of the solution was measured as % 23, 85 which displays a decrease in total solid content and boron concentration of the solution accordingly.

The performance of the solution was tested in two different adhesive recipe in production batch size by one of our customer which is a corrugated board manufacturer. In one of the cases, viscosity of the adhesive was measured as 56 seconds and the gel point of it determined as 56,5 °C when 4,375 kg powder borax per one ton of adhesive was used. These values of viscosity and gel point of the adhesive were obtained when 8,75 kg solution of boric acid and borax per one ton of adhesive was added.

In the second case, the values 71 seconds as the viscosity and 54,4 °C as the gel point of the adhesive were determined when 4,55 kg powder borax per one ton of adhesive was used. Same values for viscosity and the gel point of the adhesive were obtained with the addition of 9,1 kg solution of boric acid and borax per one ton of adhesive.

When we compared the boron content of the adhesives in each case, it was determined that the first recipe contains 496 g Boron when powder borax was used. The amount of Boron decreases to 312,7 g when the solution of boric acid, borax and polyhydroxyorganic containing solution was used. In the second adhesive, the amount of Boron which was added into the recipe with powder borax was 515,9 g. It became 325,2 g when the solution of boric acid, borax and polyhydroxyorganic containing solution was used. In each adhesive recipe, contribution of the solution of boric acid, borax and polyhydroxyorganic containing solution to the Boron content of the adhesive is lower than the powder borax does. The desired gel points and viscosities, the criteria which affect the adhesive performance, were obtained with lower amount of Boron content when boric acid, borax and polyhydroxyorganic containing solution was used. It was estimated that the presence of polyhydroxyorganic compound positively affect the properties of adhesives.

In each case, the bonding strength of the adhesives were very good regardless of the type of the boron containing compounds used.

4. Conclusion

Solution form of boron containing compound is transferred with a metering pump into the adhesive batch. The possibility of the workers' contact to the material is very low. Since the material does not contain dust, the exposure of the workers by inhalation is not concerned.

The solution form of the boron containing compound should be stored at room temperature. Low temperature storage conditions causes crystallization of the material in the container. These crystals are dissolved easily if they are left at room temperature for a while.

The viscosity and gel point of the adhesive can be adjusted easily and the very good bonding strength are obtained when the solution form of the boron containing compounds is used in adhesive preparation.

References

[1]. Chattopadhyay, A. Boron in Adhesives, International Symposium on Boron and Borides, Hawaii, 2014.

[2]. Danish Ministry of the Environment- Environmental Protection Agency, Survey of Boric Acid and Borates: Part of the LOUS Review, 2015.

[3]. Kochkodan, V., Darwish, N.B., Hilal, N., The Chemistry of Boron in Water, In Boron Separation Processes. Elsevier B.V, Netherlands, pp. 35-63, 2015.

[4]. Pappin, B., Kiefel M.S., Houston, T. A., Boron-Carbohydrate Interactions, In Studies on Glyco Biology and Glycotechnology, Intech, Rijeka, Croatia, pp. 37-54, 2012.

[5]. Bursalı, E.A. Synthesis, characterization and antimicrobial activities of boron-starch complexes (Doctoral dissertation), Retrieved from https://dspace.deu.edu.tr/xmlui/handle/1234/9205, 2010.

[6]. Anic, J., Dederich, W., Huybrecth, L. E.A., Johnson, H., European Patent No. EP 03026247 A2, Retrieved from https://patents.google.com/patent/EP0326247A2/en.