

Exploring the Role of Tributyl Phosphate as a Plasticizer in Ion-Selective Electrodes: A Comprehensive Review

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Article's Information	Abstract
Received: 13.01.2025 Accepted: 15.05.2025 Published: 15.09.2026	Tri butyl phosphate (TBP) is a plasticizer composed of organic substances that can be added to poly vinyl chloride (PVC) in order to improve its elasticity. When designing a selective polymeric membrane for potentiometric electrochemical sensors, plasticizers play a crucial role. Plasticizers increase the device's selectivity by modifying the membrane's dielectric constant. Potentiometric analysis and other analytical applications, including environmental and pharmaceutical analysis, employ instruments called ion-selective electrodes. Rapid response, elongated lifetime, sensibility, and selectivity for ion-selective electrode depend on the plasticizer type, electrode type, and the additive used in the construction of an ion-selective electrode. Numerous parameters, including the area of linear response, slope, and selectivity, are impacted by the plasticizer. The ionosphere and polymer must be compatible with the plasticizer in the membrane. One appropriate plasticizer for the creation of ion-responsive, selective electrodes is tri-butyl phosphate (TBP).
Keywords: Tri butyl phosphate, Ion selective electrode, Poly vinyl chloride, Elasticity.	
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1. Introduction

Tri butyl phosphate (TBP) has a molecular formula of $(C_4H_9)_3PO_4$ with a chemical structure as shown in Figure-1. Its molecular weight is 266.31 g/mol. TBP can be described as an odorless, colorless to yellow liquid. Its melting point is less than $-112^\circ F$, and its boiling point is $552^\circ F$ at 760 mmHg. Soluble

in diethyether, benzene, and carbon disulfide, miscible with ethanol [1]. Applications of TBP as a plasticizer with n-butanol. Polyvinyl chloride (PVC) is commonly used in making plastics. Currently, there is a growing demand for TBP in the global market [2]. The TBP market size and global forecast are shown in Figure 2.

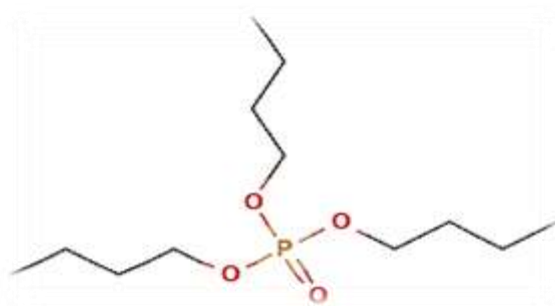


Figure 1. TBP structure [1]

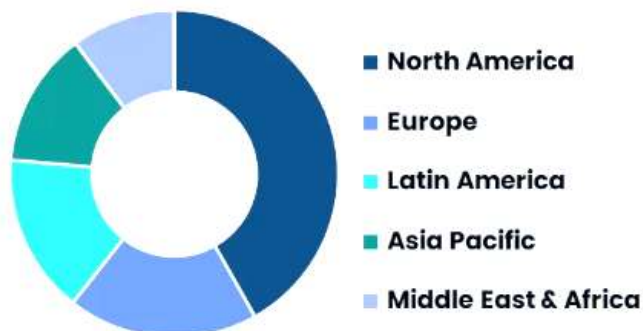


Figure 2: TBP market size and global forecast

A plasticizer is a material that is combined with another material to increase that material's functionality and plasticity by allowing the material's internal intermolecular bonds to be broken. The TBP market is anticipated to grow significantly in the Asia Pacific region [3]. The market is divided geographically into five areas: North America, Europe, Asia Pacific, Latin America, and the Middle East and Africa. In terms of demand, the North American region leads the global TBP market [4]. Using plasticizers to produce plastic results is not a new technique. In the 1800s, it was used to change the properties of polymers. Celluloid manufacturers at the time used regular camphor and castor oil for plasticization, but these weren't appropriate for all final products. Later, in 1912, TBP was combined with camphor auxiliary oil, marking the beginning of the use of esters as plasticizers [5]. Phthalic acid esters were first used as plasticizers in 1920, and they continue to be the most widely used class of plasticizers in the twenty-first century [6]. The amazing results of plastic and its many applications have led to the development of better plasticizers than ever before to see specific supplies. A wide range of readily available commercial plasticizers have been improved over the past 50 years due to safety and health concerns [7]. To reduce the use of plastic products, experts and businesses are also eager to improve plasticizers by utilizing novel bio-dependent substances made from renewable and biodegradable resources. It makes sense to believe that the best plasticizers for biopolymers would be biodegradable [8]. They contain a small amount of tartrates, fatty acid esters, esters of azelaic and sebacic acid, chlorinated hydrocarbons, and benzoates. The use of conventionally constructed plasticizers with low toxicity is currently growing. These plasticizers contain esters of fatty acids as well as epoxidized vegetable oils' fatty substances, such as those found in linseed, soybean, sunflower, and castor oils [9].

TBP forms stable hydrophobic complexes with certain metals when it is used as a plasticizer and solvent. These complexes are soluble in organic solvents and supercritical CO₂ [10]. As part of the purification process of natural ores, trichloroethylene and di(2-ethylhexyl) phosphoric acid are used to extract uranium from a solvent. [11] Additionally, it is a component of the PUREX process in nuclear reprocessing [12]. This study demonstrates the use of TBP in the potentiometric analysis of different medications.

2. TBP as a Plasticizer

TBP is used in many different applications, including plastic and vinyl resins, coatings, lacquers, and ink. TBP and other comparable phosphate ester plasticizers have better fire retardant qualities than phthalates, which is one of their main advantages over phthalates. Because of its high halogen content however, the addition of some plasticizers may compromise this quality. The use of phosphate ester plasticizers may help to mitigate this issue [13]. Plasticizers can be categorized into two types: external and internal. External plasticizers when added to polymers can become less stable [14]. In this way, the plasticizer molecules can be lost through evaporation even though they cooperate with the polymer chains and are not chemically bound to the base bonds. Conversely, the core of the polymer particles that can polymerize collectively to form a polymer formation is the internal plasticizers [15]. Some internal plasticizers have bulky designs that give the polymers extra room to move to different places and stop the polymers from adhering to one another. The result is softer polymers by lowering the temperature, where the temperature dependence is evident [16]. The choice of using an external plasticizer, as opposed to an internal plasticizer, depends on the desired product outcomes. They are called primary and secondary plasticizers

[17]. The polymer must be mixed with a basic plasticizer if the polymer has highly concentrated and is categorized as a solvent. This type of basic plasticizer is used as a one-component, at normal temperatures. The polymer should be quickly synthesized and mixed with compatible facultative plasticizers in order to further develop production properties [18]. In general, plasticizers that are based on biopolymer films fall under two categories: water-soluble and insoluble materials [19]. By adding the polymer, hydrophilic plasticizers might dissolve in aqueous media and can induce diffusion expansion of the water in the polymer [20]. On the contrary, plasticizers such as hydrophobic materials can decrease water absorption [19]. It is possible to obtain an insoluble polymer-based plasticizer using a plasticizer with a stirring speed of the polymeric dispersions [21].

3. Plasticizers Used in Polymeric Membrane Ion-Selective Electrodes

It is difficult to handle the liquid membrane for the electrodes. Additionally, since the liquid membrane would leak, using ion-selective electrodes was prohibited [22]. However, a significant advancement in ion-selective electrode analysis was made possible by changing the polymeric membrane [23]. The modification involved combining a polymeric membrane with cyclohexanone or tetrahydrofuran as the solvent used in the membrane formulation with a plasticizer to create ion-selective electrodes [24]. Among the plasticizers that can be used are ortho-nitrophenyloctyl ether (NPOE), dibutyl phthalate (DBP), tris (2-ethylhexyl) phosphate (TEHP), dinonyladipinate (DNA), tris (2-ethylhexyl) phosphate (TBP), dioctylphthalate (DOP), and bis (2-ethylhexyl) adipate (DOA). [24].

Table -1: Some studies for the characterization of electrodes depending on TBP plasticizer

Main aim of the research	Reference
Chromium (III)-selective electrode based on a macrocyclic compound.	[1] Singh A. Analyst. 1999;124(4):521-5.
New Cimetidine Selective Electrodes are Being Built to Determine Cimetidine Content in Prescription Medicines.	[2] Sayhood SK, Hussain J, Hussain L, Ahmed O, Muyad M. Journal of Kufa for Chemical Sciences. 2012;1(6).
Building and potentiometric analysis of PVC matrix membrane-based chloramphenicol selective electrodes.	[3] Muhamad YH. Al-Nahrain Journal of Science. 2015 Mar 1;18(1):1-8.
The creation and investigation of cephalixin-specific electrodes and their use in pharmaceutical products..	[4] Al-Saidi KH, Nassory NS, Maki SA. Al-Mustansiriyah Journal of Science. 2010;21(6).
The preparation, analysis, and use of derivative spectrophotometers in the application of amoxicillin-selective electrodes in pharmaceutical products.	[5] Al-Saidi KH, Nassory NS, Maki SA. Al-Nahrain Journal of Science. 2009 Mar 1;12(1):29-37.
Pharmaceutical analysis uses polymeric membrane sensors for the selective measurement of metoclopramide hydrochloride.	[6] Al-Haideri AM, Abdulla NI, Malih IK. Iraqi Journal of Pharmaceutical Sciences 2012;21(1):70-7.
Tramadol-PVC membrane electrodes' detection limit as affected by plasticizers and ion-exchangers.	[7] Shawish HM, Ghalwa NA, Al-Dalou AR, Zaggout FR, Saadeh SM, Abou Assi AA. methods. 2011 Jul 1;8:11.
Preparation and Application of Amiloride Hydrochloride Selective Electrodes in Prescription Medicines..	[8] Khaleda H. Al-Mustansiriyah Journal of Science. 2010;21(6).
New Ethambutol Selective Electrodes are Being Built to Identify Ethambutol in Prescription Medicines.	[9] Nassory NS, Al-Haideri AM, Sayhood SK. Al-Mustansiriyah Journal of Science. 2010;21(6).
preparing Selective Electrodes for Promethazine Hydrochloride in a PVC Matrix Membrane.	[10] Al-Saidi KH, Ahmed ZW. Journal of Al-Nahrain University. 2011 Dec 1;14(4):11-7.
preparing ion-selective membrane electrodes for pharmaceutical preparations and the potentiometric measurement of atenolol in its pure form.	[11] Khaleel AI. Tikrit Journal of Pure Science. 2012;17:2.

Preparing Ion Selective Electrodes for measuring Fe (III) and in Prescription Medicines.	[12] Al-Saidi KH, Aziz WR. Baghdad Science Journal. 2013 Dec 1;10(4):1211-7.
creation and evaluation of a PVC matrix membrane-based atenolol selective electrode.	[13] Nassory NS, Maki SA, Ali MA. Turkish Journal of Chemistry. 2007;31(1):75-82.
Identifying Sulfamethoxazole in Prescription Medicines using Polymeric Ion Selective Electrode	[14] Abraham SA, Al-Saidi KH. Al-Nahrain Journal of Science. 2015;18(2):25-32.
Investigation of cobalt (III) corrole as the neutral ionosphere for polymeric membrane electrode-based nitrite and nitrate detection.	[15] Yang S, Meyerhoff ME. Electroanalysis. 2013 Dec;25(12):2579-85.
Ion-selective electrode for lanthanum determination in standard samples.	[16] Khalil S. Analytical letters. 2003 Jan 6;36(7):1335-49.
Ion-selective electrodes for the identification of pharmaceuticals containing nitrogen.	[17] Kulapina EG, Barinova OV. Journal of Analytical Chemistry. 2001 May;56:457-60.
Detecting Serotonin using Ion-selective Electrodes	[18] Bliem C, Fruhmenn P, Stoica AI, Kleber C. Electroanalysis. 2017 Jun;29(6):1635-42.
Regularities and abnormalities in the plasticizer's effect on ion-selective electrodes' selectivity to physiologically active amine cations.	[19] Egorov VV, Astapovich RI, Bolotin AA, Vysotskii DL, Nazarov VA, Matulis VE, Ivashkevich OA. Journal of Analytical Chemistry. 2010 Apr;65:404-13.
Tramadol-PVC membrane electrode optimization using ion-pair complexes and various plasticizers.	[20] Shawish HM, Saadeh SM, Al-Dalou AR, Ghalwa NA, Abou Assi AA. Materials Science and Engineering: C. 2011 Mar 12;31(2):300-6.
Trimethoprim Determination with Drug-Selective Electrodes.	[21] Abraham SA, Abass AM, Ahmed AH. Asian J Pharm Clin Res. 2019;12(6):83-7.
An electrode that selectively detects water hardness ions using a neutral carrier.	[22] Hu Z, Qi D. Analytica chimica acta. 1991 Jul 15;248(1):177-81.

4. Using TBP in Green Production

The use of green chemistry in the field of analytical chemistry is exemplified in using chemical plasticizers such as Tri butyl phosphate (TBP) in the manufacture of electrodes to avoid pollution. Nevertheless, there is an absence of written scholarly research about it. There are risks associated with the actual compound in the composition of the compound, its raw materials and biodegradation. The engineered processes used to create it are analyzed according to green chemistry principles using well-known solvents or auxiliary. Using such methods makes it safer, and has less chemical synthesis hazard. The benefits of those methods can also include waste prevention, lower number of derivatives and energy efficiency [47]. However, there is a continuous investigation of pollution prevention. In addition, there is a lack of published literature on green synthesis techniques used to produce plasticizers. However, the principles mentioned above can serve as a foundation for further research [48]. Sustainable materials that do not disrupt food production should be considered to prevent economic and social impacts [49, 50]. For instance, abundant raw materials from agri-

mechanical deposits and biomass can be utilized as chemical raw materials for different plasticizers [51].

5. Conclusions

This review has addressed the use of plasticizers such as tributyl phosphate plasticizer in formulating a membrane (film) that can be used in the ion-selective electrodes. Tributyl phosphate plasticizer affects the KPIs of ion-selective membrane electrodes as well as their selectivity, slope, and straight response. Using a plasticizer for formulating the membrane must be applicable to the polymer as well as to (ionosphere). Identification of an upper plasticizer for optimizing a particle-specific membrane (film) generally involves exploratory tests. These tests determine the ionosphere and plasticizer obtained from the maximal reaction qualities of the ion-selective electrodes. A tributyl phosphate plasticizer represents an example of a most suitable plasticizer for a selective electrode scheme.

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