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Article

# Fabrication of Functionally Modified Alginate-based pH-Responsive Hydrogels and their Silver Nanocomposites for Biomedical Applications

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**ABSTRACT**

Hydrogels have significant economic potential and are attractive prospects for use as biomedical devices, particularly in medication administration and wound healing. In addition, their metal nanocomposites show promise as catalysts in organic transformations. Nevertheless, developing a method to create hydrogels using naturally occurring polysaccharides that have been changed to possess certain functions and can meet the aforementioned criteria is a significant difficulty. The current study focuses on propylene glycol alginate-co-poly (acrylamide). The chemical is a copolymer made up of bis (2-methacryloyloxy) ethyl phosphate and 3-sulfopropyl methacrylate potassium salt. PASB co-polymeric hydrogels were synthesized by a straightforward free radical polymerization process employing potassium persulfate as a crosslinking agent. In addition, we utilized *Annona Cherimoya* aqueous leaf extract as the reducing agent to create silver nanoparticles (PASB-Ag) using PASB hydrogels as templates in a green method. The PASB and PASB-Ag hydrogels underwent characterization using Fourier transform infrared spectroscopy, ultraviolet-visible, X-ray diffraction, scanning electron microscopy, and EDAX techniques. The PASB hydrogels effectively contained the anti-cancer medication doxorubicin, resulting in an increase in drug concentration from 40.32 ± 1.3 to 74.02 ± 0.8. *In vitro* cumulative drug delivery tests were conducted at pH 1.2 and 7.4 and at a temperature of 37°C.

**Key words:** Hydrogel, Alginate, Drug delivery, Doxorubicin, Anti-cancer.

## 1. INTRODUCTION

Hydrogels have recently emerged as attractive materials for a variety of biomedical and biotechnological applications owing to their unique features, which include high water content, biocompatibility, and customizable mechanical properties [1,2]. Alginate-based hydrogels have received substantial interest because of their inherent biocompatibility, minimal toxicity, and ease of gelation under moderate circumstances [3,4]. Furthermore, alginate hydrogels may undergo reversible swelling or deswelling in response to environmental stimuli, making them ideal for the creation of smart, responsive materials. Changing the function of alginate-based hydrogels to make them react differently to outside stimuli, like changes in pH, has been an important area of research. pH-responsive hydrogels have sparked widespread attention because of their potential uses in drug delivery, tissue engineering, bio-sensing, and controlled release systems. Researchers often modify alginate-based hydrogels by incorporating pH-sensitive moieties, such as ionizable groups or pH-responsive polymers, into the hydrogel matrix [5,6]. Chemical conjugation, physical mixing, and crosslinking using pH-sensitive cross-linkers are among the techniques available for achieving these alterations. Researchers may tailor the pH-responsive behavior of a hydrogel to particular application needs by carefully choosing and refining its composition and structure.

Cross-linked polymers known as hydrogels, or hydrophilic polymer networks, are able to absorb large volumes of water without breaking down [7-9]. Hydrogels are able to hold onto their water-absorbing properties due to the cross-links that connect the polymer chains and their hydrophilic functional groups on the polymer backbone. Because of the water content, the hydrogel allows various solute molecules to diffuse freely, while the polymer acts as a scaffold to keep the water cohesive. On a macroscopic scale, hydrogels are characterized by the formation of a single polymer molecule, with the polymer chains inside the gel joined together to create a unified unit. At the macro level, the changes in shape of the elastically active polymer chains can be seen in hydraulic gel samples. Owing to their ability to imitate the properties of real soft tissue, hydrogels find extensive use in various areas, such as the pharmaceutical industry, agriculture, and energy systems [10].

Researchers fabricated hydrogels from both natural and synthetic polymers. Polysaccharide-based hydrogels have demonstrated good biocompatibility and biodegradability, rendering them valuable in various applications such as food, biomedical, tissue engineering, and drug delivery [11]. Propylene glycol alginate (PGA) is a high-molecular-weight linear polysaccharide made up of L-guluronic acid (69–35%) and 1,4-linked-D-mannuronic acid (31–65%) that have been chemically changed from alginate by an esterification reaction [12-14]. For example, in the biomedical field, PGA has been

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**Table 1:** Chemical quantities, equilibrium swelling ratio, and encapsulation efficiency of PASB hydrogels.

| Sample code | Propylene glycol alginate (mL) | Am (gm) | sulfopropylmethacrylate (gm) | Bis(2-methacryloyloxy) ethyl phosphate 10% v/v (mL) | Potassium per sulfate 10% (mL) | % Swelling equilibrium ratio | % EE |
|---|---|---|---|---|---|---|---|
| PASB-1 | 5.0 | 0.5 | 0.5 | 2 | 1.0 | 2841 | 43.39±1.3 |
| PASB-2 | 5.0 | 0.5 | 1.0 | 2 | 1.0 | 4727 | 49.41±1.4 |
| PASB-3 | 5.0 | 0.5 | 1.5 | 2 | 1.0 | 5085 | 58.80±0.8 |
| PASB-4 | 5.0 | 0.5 | 1.0 | 1 | 1.0 | 5727 | 74.02±0.8 |
| PASB-5 | 5.0 | 0.5 | 1.0 | 3 | 1.0 | 4393 | 40.32±1.3 |

Am: Acryl amide

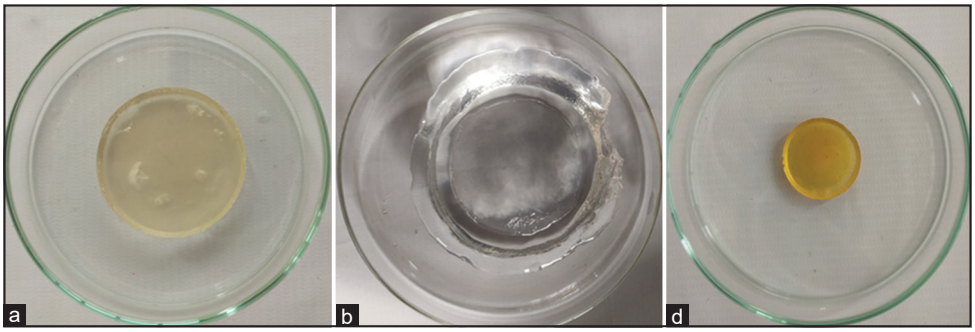



**Figure 1:** Photographic images of PASB hydrogel, (a) Hydrogel at the time of preparation, (b) Hydrogel at the time of swollen and (c) Hydrogel at the time of dried state.

used as an *in situ* gelling agent for drug delivery; as a coagulant to induce the destabilization and coagulation of casein micelles in milk; and as a stabilizer, emulsifier, or thickener in various food products such as yogurt, lactic drinks, dressings, and sauces. $Ca^{2+}$ chelation with glycol residues creates functional junction zones between individual alginate chains, resulting in the production of a three-dimensional network.

The ability of polymer networks to swell is stronger in alkaline environments than in the gastrointestinal region. This is because the ester contains the cross-linker bis (2-methacryloyloxy) ethyl phosphate. In cell physiology, phosphate esters are among the most important building blocks, along with DNA, RNA, lipids, and proteins. Phosphate esters could be used in biomedicine because they are biodegradable, biocompatible, and can be conjugated. They could also be used for controlled release drug delivery because enzymes can break them down. When used alone, doxorubicin (DOX) is plagued by major side effects such as nausea, vomiting, diarrhea, constipation, alopecia, bone marrow toxicity, stomatitis, cumulative and acute cardiotoxicity, and extravasation [15]. However, DOX has been shown to be highly effective in the treatment of ovarian, bladder, and colon cancers, in addition to solid tumors and hematological malignancies. Typically, liposomes and polymers ionize or pH-radiate across to load DOX into the aqueous interior. Encapsulating DOX in a polymeric matrix has been shown to increase its calculation in tumors and increase its duration in circulation [16,17].

## 2. EXPERIMENTAL

### *2.1. Materials*

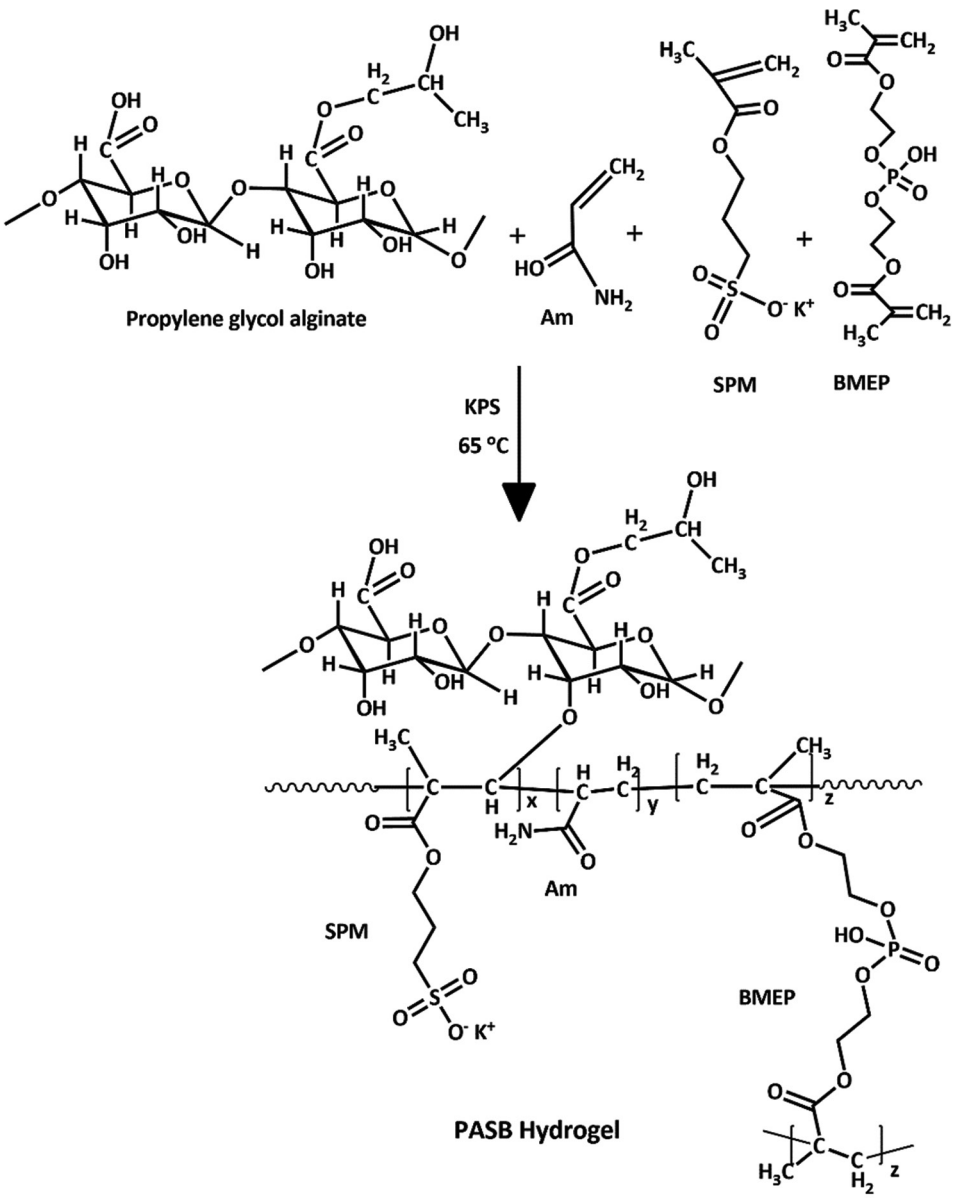
We obtained PGA from S.D. Fine Chemicals in Mumbai, India. Sigma-Aldrich in the United States of America provided us with the 3-sulfopropyl methacrylate (SPM) potassium salt and the bis(2-methacryloyloxy) ethyl phosphate (BMEP). Merck India provided acrylamide and potassium per sulfate (KPS). LC laboratories in the United States provided DOX or DOX hydrochloride. Sodium hydroxide, hydrochloric acid, and silver nitrate were acquired from S.D. Fine chemicals, a Mumbai-based company in India. Each investigation only used double-distilled water (DDW) and utilized the compounds in their unaltered state.

### *2.2. Synthesis of Propylene Glycol Alginate-co-Poly(Acrylamide)-co-Poly(3-Sulfopropyl Methacrylate Potassium Salt)-cl-Poly(Bis(2-Methacryloyloxy) Ethyl Phosphate) [PASB]-Based Hydrogel*

A simple free radical polymerization method was used to synthesize hydrogel [7,18,19] from PGA, acrylamide, 3-sulfopropylmethacrylate potassium salt, and bis(2-methacryloyloxy) ethyl phosphate (cross-linker) using KPS at 65°C. The 5 mL of PGA (2%) solution was taken in a 100 mL beaker, and to this known quantity of monomers were added [Table 1] and stirred for homogeneous solution. Further, it was mixed with 2.0 mL of a cross-linker agent (BMEP, 10% aqueous solution) with constant stirring, and finally, 2 mL of initiator (KPS, 10% aqueous solution) was added and stirred for one more hour. The resulting solution was placed in a water bath (at 65°C) for 5 h to get the transparent hydrogel. Once the polymerization was completed, the hydrogels were immersed in DDW to get rid of any unreacted monomer leftovers. We immersed the hydrogels in DDW for 2 days at room temperature, changing the water twice a day. We dried the swollen hydrogels at room temperature for 3 days and then in a hot air oven at 45°C until they reached a constant weight. Digital photographs of the hydrogel are presented in Figure 1, and plausible schematic chemistry of the hydrogels is shown in Scheme 1.

### *2.3. Green Synthesis of Silver Nanoparticles (AgNPs) [20-22]*

The fresh leaves of *Annona Cherimoya*, a medicinal plant, were gathered on the premises of Yogi Vemana University, Kadapa, and Andhra Pradesh, India. These leaves were washed with tap water and then with DDW to remove any dust particles present. The first step involves the fragmentation of the leaves into smaller segments, followed by grinding them into powder with a mixer grinder. 0.5 g of leaf powder was measured and placed into a 250-mL beaker containing




**Scheme 1:** Plausible schematic chemistry of PASB hydrogels.

50 mL of DDW. This beaker was placed on a magnetic stirrer with a stirring rate of 200 rpm at 65°C for 5 h. The resulting solution was filtered using Whatman filter paper to obtain a clear solution. This extract was stored in a cool, dark place for use in subsequent experiments.

To achieve the green synthesis of silver nanoparticles using the PASB hydrogel template, a large amount of dried PASB hydrogels was carefully weighed and transferred to distilled water for a period of 48 h to ensure proper equilibration. We transferred the swollen PASB hydrogel to a separate beaker containing 20 mL of a 5 mM aqueous silver nitrate solution. The system equilibrated for 24 h. In this particular scenario, the majority of silver ions undergo exchange from the solution into hydrogel networks through the involvement of -OH, -$CONH_2$, and -COOH groups present in the hydrogel chain. An ion exchange process accommodates the remaining metal ions within the vacant spaces of the hydrogel network. The $Ag^+$ ion solution-absorbed PASB hydrogel was subsequently placed into a separate beaker containing 20 mL of an aqueous extract of *A. Cherimoya* leaves. The mixture was then allowed to reduce $Ag^+$ ions into silver nanoparticles ($Ag^o$) for 2 h. The formation of Ag nanoparticles was first confirmed through the color change, i.e., from light orange to black. The PASB hydrogel nanocomposites were subjected to a washing process using DDW and subsequently dried at room temperature, followed by further drying in a hot air oven set at 45°C.

### *2.4. Swelling Studies*

The swelling properties of the PASB hydrogels were investigated in DDW at an ambient temperature (i.e. 32°C) [19]. The known amounts of hydrogels were immersed in 100 mL of a beaker containing 60 mL of DDW. The swollen hydrogel was weighed by gently (at pre-designed intervals) removing any water attached to its surface using tissue paper. The equilibrium swollen hydrogels were allowed to dry at room temperature and simultaneously measured weight at pre-designed intervals for deswelling studies. Furthermore, pH-dependent equilibrium swelling studies were conducted in different pH solutions [1,3,5,7,9,11]. The % swelling ratio (%SR) and % swelling equilibrium ratio were determined by applying the following formulas to the mass readings.

$$\%\ Swelling\ ratio\ of\ PASB\ hydrogel = \left(\frac{m_s - m_d}{m_d}\right)$$

$$\%\ Equilibrium\ swelling\ ratio = \left(\frac{m_e - m_d}{m_d}\right)$$

Here, $m_s$ is the weight of swollen hydrogel, $m_d$ is the weight of dry hydrogel weight, $m_e$ is the weight of equilibrium condition.

### *2.5. Drug Loading, Encapsulation Efficiency and in vitro Drug Release Studies [19,23,24]*

To load DOX onto PASB hydrogel formulations, we transferred 500 mg of samples to 30 mL of DOX solution at a concentration of 1 mg/mL. After 24 h, the mixture equilibrated at ambient temperature. The drug solution that had absorbed the swollen hydrogels underwent a rapid rinsing with DDW to eliminate any residual drug molecules present in the hydrogels' desiccated state. To determine the efficacy of PASB hydrogels in encapsulating DOX, 15 mg of desiccated hydrogels were submerged in phosphate buffer solution (PBS) for 24 h before the gels were pulverized in an agate mortar to extract the DOX from the matrix. DOX concentrations were measured by a UV-visible spectrometer (LAB India, DS-8000, India).

$$\%\ Drug\ loadind = \left(\frac{Amount\ of\ drug\ loaded\ PASB\ polymer\ hydrogel}{Amount\ PASB\ polymer\ hydrogel}\right) \times 100$$

$$\%\ Encapsulation\ efficiency = \left(\frac{Actual\ loading\ of\ DOX}{Theoritical\ loading\ of\ DOX}\right) \times 100$$

### *2.6. Antimicrobial Activity*

The antimicrobial activity procedure was adopted by our laboratory in previous reports [22,25]. We examined the antimicrobial activity of the silver nanocomposites hydrogel (PASB-Ag) using the disc diffusion method. We prepared the initial nutrient agar medium by combining 5.0 g of peptone, 3.0 g of beef extract, and 5.0 g of sodium chloride (NaCl) in DDW. We sterilized the final agar medium in an autoclave for 30 min. at 121°C and 15 lbs. We transferred the medium to petri dishes. We subjected Gram-positive and Gram-negative bacteria, including *Escherichia coli*, *Bacillus*, *Pseudomonas aeruginosa*, and *Corynebacterium*, to the assay. After solidifying the media solution, we applied 100 mL of each bacteria culture to the inoculated petri dish using a paper disc and a sterile spreader on the solid surface area. Ampicillin was used as the antibiotic. 5 mg/5 mL of the sample aqueous solution was prepared, and 30 mL was added to each well. The solutions were then incubated at 37°C overnight. We subsequently assessed bacterial zone inhibition.

### *2.7. Characterization*

Fourier transform infrared spectroscopy (FTIR-Perkin Elmer Spectrum Two, UK) was used to find the functional groups in the polymers and prepare polymer nanocomposites. X-ray diffraction (XRD) (Rigaku, Miniflex 600, Japan) was used to illustrate the structure and crystalline nature of the composite materials. Scanning electron microscopy (FE-SEM, Hitachi S-4800) was used for the confirmation of the surface morphology and energy-dispersive X-ray spectroscopy (EDAX) for the elemental analysis of the composite materials. We used the USP tablet analyzer (LAB India, DS-8000, and India) to investigate the *in vitro*

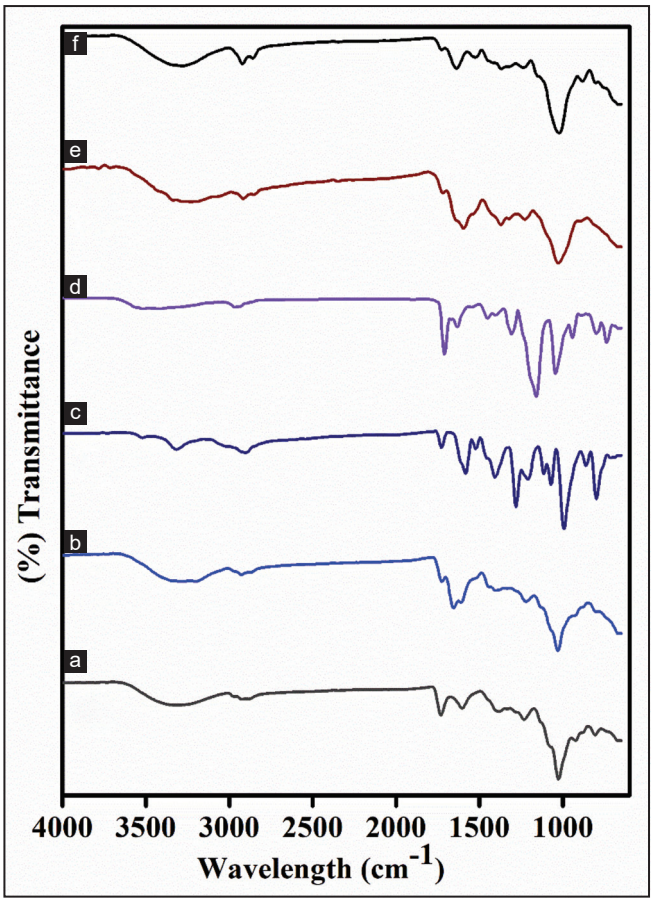



**Figure 2:** Fourier transform infrared spectroscopy spectra of (a) pure polymer, (b) pure PASB hydrogel, (c) pristine doxorubicin (DOX), (d) DOX-loaded PASB hydrogel, and (e) aqueous leaf extract of *Annona Cherimoya,* (f) silver nanocomposite of PASB hydrogel.

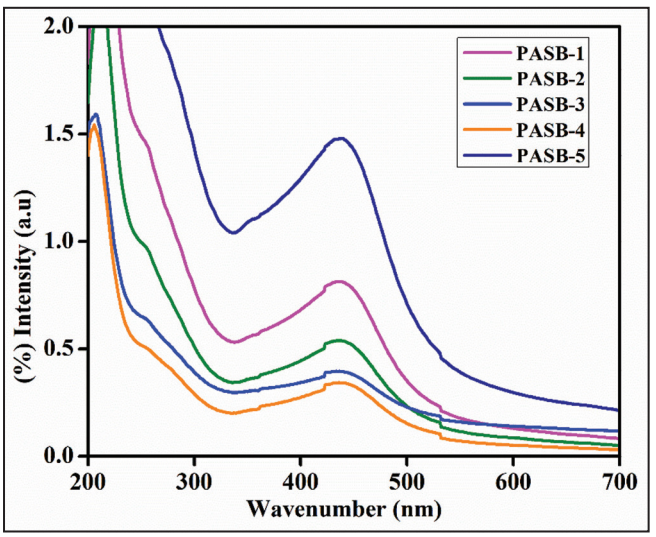



**Figure 3:** Ultraviolet-visible spectroscopy of PASB-silver nanocomposites.

release of DOX from PASB hydrogels. The researchers conducted the dissolution studies at 100 rpm and 37°C in aqueous PBS with pH values of 1.2 and 7.4. Using formulations weighing around 100 mg, the researchers filled the baskets with 500 mL of buffer solution for this investigation. The researchers collected 5 mL of drug-loaded samples

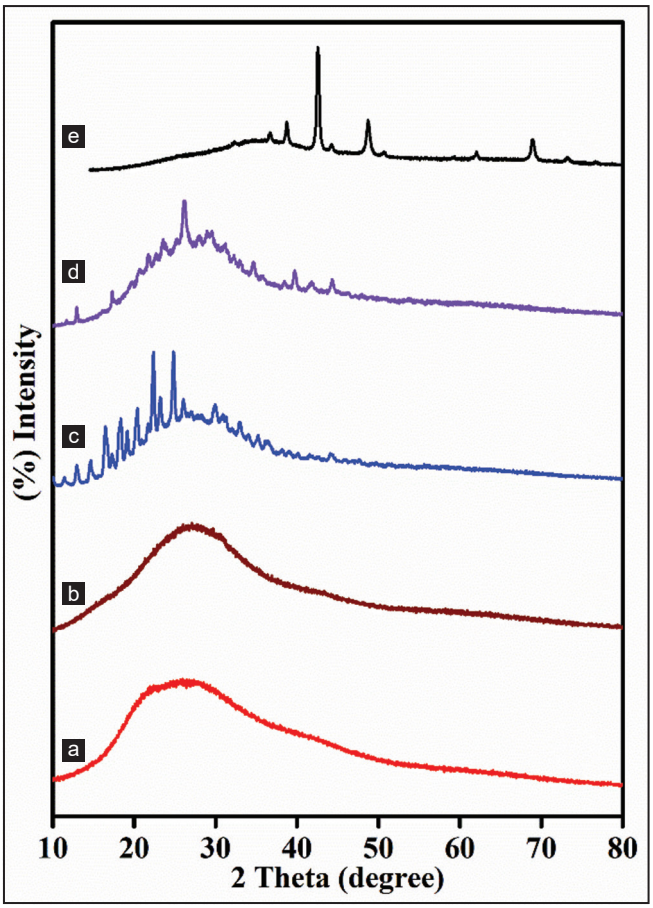



**Figure 4:** (a) Pure polymer, (b) pure PASB hydrogel, (c) pristine Doxorubicin (DOX), (d) DOX-loaded PASB hydrogel, and (e) silver nanocomposite of PASB hydrogel.

at regular intervals. An ultraviolet spectrophotometer (LAB India, UV-3092) was used to evaluate the samples that were collected, maintaining a constant wavelength of 490 nm.

## 3. RESULTS AND DISCUSSION

The potential application of pH-responsive hydrogels is the regulated discharge of anti-cancer drugs. However, they frequently experience prolonged release times and site-specific side effects as a result of the drug's hydrophilic nature and short half-life [16,26-28]. The study's goal is to make a stable pH-responsive hydrogel from PGA, acrylamide, 3-SPM potassium salt, and BMEP so that we can create a possible anti-cancer drug delivery system that can release water-loving drugs precisely where they are needed. Scheme 1 illustrates the formation of PASB hydrogels. An aqueous solution containing PGA, 3-sulfopropyl methacrylate potassium salt with sulfopropyl groups, polyacrylamide, and bis(2-methacryloyloxy) ethyl phosphate was combined in this mixture at the outset. We utilized KPS as the initiator to facilitate the polymerization process. We produced the hydrogels by using varying concentrations of SPM and BMEP, while keeping acrylamide, polysaccharide solution, and APS constant. Scheme 1 demonstrates the potential physicochemical interactions among BMEP, acrylamide, polysaccharide PGA, and SPM. We were expected to suggest potential interactions of PASB hydrogel, including (i) forming covalent bonds between SPM, acrylamide, and BMEP and (ii) the physico-chemical interaction of hydrogel bonds between PGA polysaccharide and SPM.

### *3.1. Fourier Transform Infrared Spectroscopy*

From Figure 2, pure PASB hydrogel exhibited the significant peaks for PGA, a broad peak observed at 3408 $cm^{-1}$ corresponds to –OH, the frequencies of 2931 and 2841 $cm^{-1}$ -$CH_3$, -$CH_2$ stretching vibrations, 1733 $cm^{-1}$ is a -COOH stretching, and 1107 $cm^{-1}$ -C-O-C- is a bending vibration [Figure 2b]. For acrylamide and 3-sulfopropylmethacrylate potassium salt, 1733 $cm^{-1}$, 1661 $cm^{-1}$, 1192, 1039 $cm^{-1}$ represent

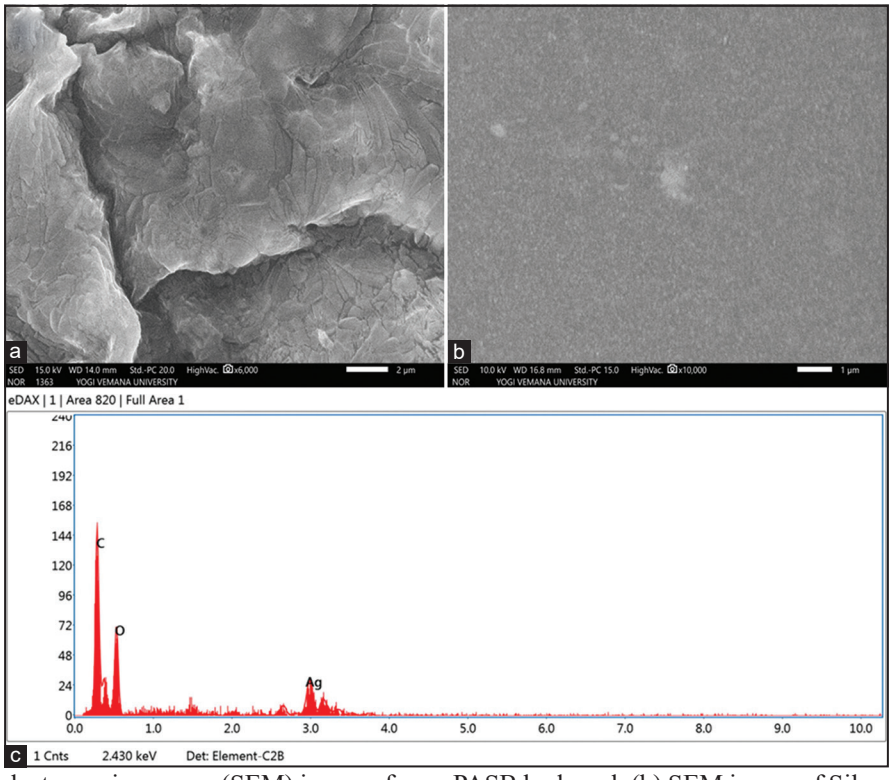



**Figure 5:** (a) Scanning electron microscopy (SEM) image of pure PASB hydrogel, (b) SEM image of Silver (Ag) nanocomposite of PASB hydrogel, (c) EDAX spectrum of Ag nanocomposite of PASB hydrogel.

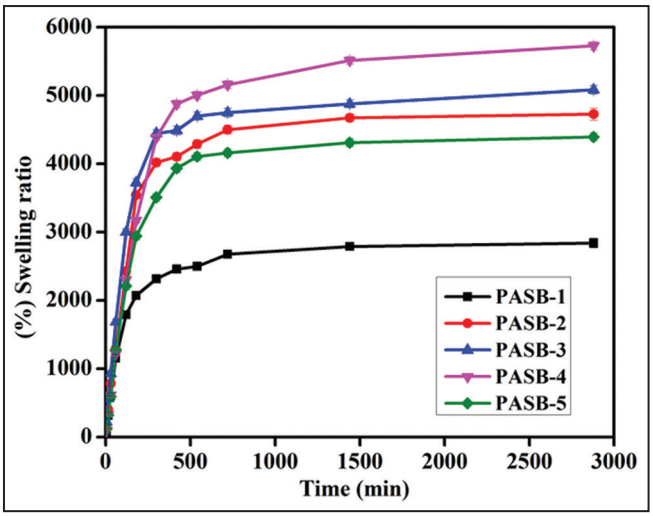



**Figure 6:** Swelling kinetics of all compositions of PASB hydrogels.

the -C=O stretching vibrations, -(C=O)-NH-, $-SO_3^-$ symmetric and asymmetric stretching vibrations. 1134 and 1073 $cm^{-1}$ P-O, -C-O stretching peaks represent the bis(2-methacryloyloxy) ethyl phosphate. Pristine DOX exhibited significant peaks of -OH, -NH stretching vibrations at 3319 $cm^{-1}$ and 1724 $cm^{-1}$ in Figure 2c. In addition, -C=C- stretching vibrations observed at 1579 $cm^{-1}$. The DOX-loaded PASB hydrogel exhibited both drug and polymer peaks, and these results indicate that the drug molecule is present in the polymer matrix [Figure 2d].

Figure 2e, a pure aqueous leaf extract of *A. Cherimoya*, showed an absorption peak at 3380 $cm^{-1}$ for phenolic-OH stretching vibration. Furthermore, significant peaks were detected at 2931.42 and 2849.12 $cm^{-1}$ for aliphatic -C-H symmetric and asymmetric vibrations, respectively. Peaks at 1641.40 $cm^{-1}$ and 1444.68 $cm^{-1}$ correspond to -C-H symmetrical twisting vibrations in the polymer networks, while a peak at 1032.97 $cm^{-1}$ indicates C-O stretching vibrations. Capping and stabilizing agents are crucial and significantly used during the Ag nanoparticle production process. Hence, in this process, various functional groups found in the extract's phytochemicals may be involved. According to the findings, *A. Cherimoya* plant leaves are rich in polyphenolic, flavonoid, and glycoside chemicals that are involved in the production and stability of Ag nanoparticles.

### *3.2. Ultraviolet-visible (UV-Vis) Spectrometer*

Figure 3 represents the UV-vis spectroscopy analysis of the green synthesis of AgNPs using the PASB hydrogel template (PASB-Ag silver nanocomposite). UV-vis spectroscopy analysis confirms that $Ag^+$ ions are reduced to Ag° nanoparticles in 300 min at room temperature and in the presence of the PASB hydrogel polymer matrix using an aqueous leaf extract of *A. Cherimoya*. The UV-vis spectra of PASB hydrogel formulations containing Ag° nanoparticles (Ag nanocomposites) are illustrated in the Figure 3. The UV-vis spectra of PASB hydrogel formulations containing Ag° nanoparticles exhibited absorption maxima at 437 nm, ranging from 420 nm to 450 nm. The highest absorption peak was seen in formulation PASB-5, which had more cross-linkers and was better at holding Ag° particles in place in the hydrogel network. In contrast, formulation PASB-4 had the lowest absorption peak as a consequence of its low cross-linker content. The size-dependent quantum mechanical phenomenon known as surface plasmon resonance gave rise to these peaks [20]. The surface plasmon resonance of a hydrogel is highly dependent on the solvent, particle size, and dielectric properties of the medium.

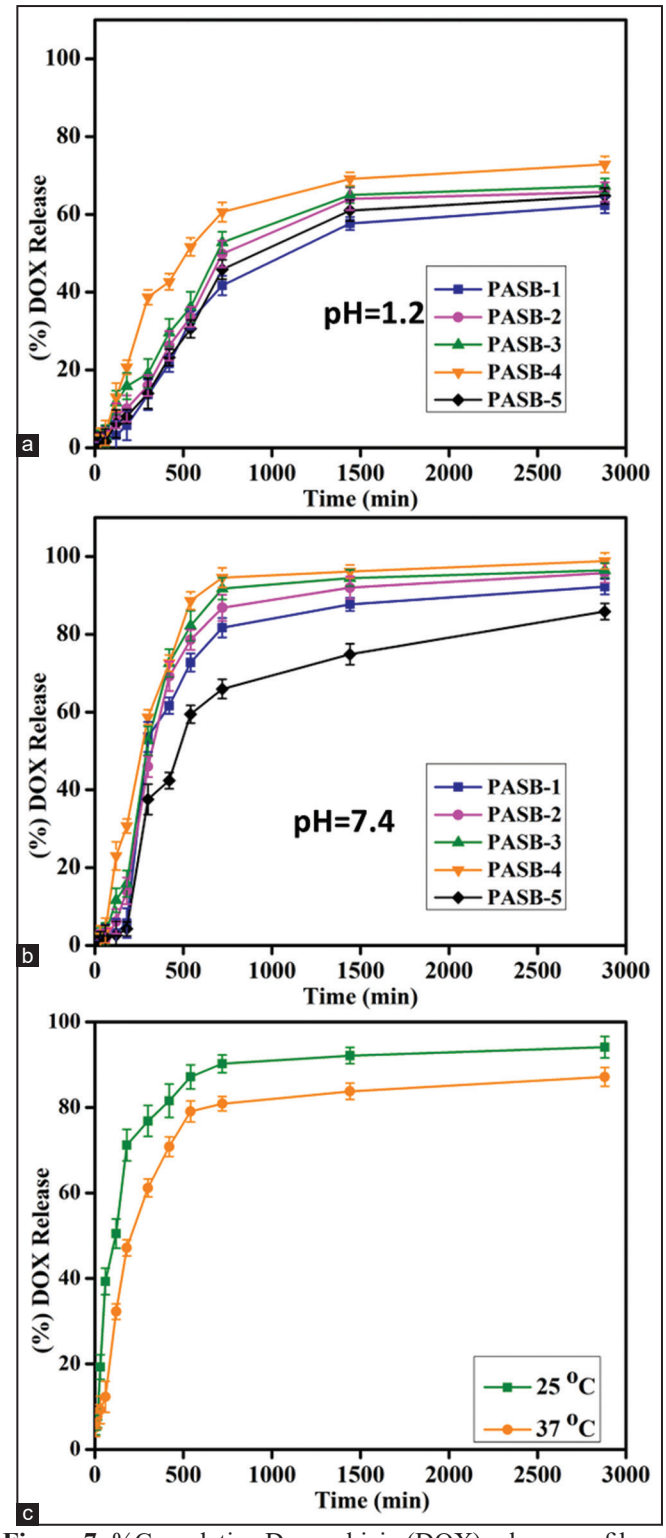



**Figure 7:** %Cumulative Doxorubicin (DOX) release profiles of PASB hydrogels in pH 1.2 (a) and 7.4 (b) at 37°C and DOX release in 25°C and 37°C at pH 7.4.

### *3.3. X-ray Diffraction Analysis of the PASB-Ag Nanocomposites*

The XRD pattern of DOX showed an intense peak at two theta values of 16.41°, 18.46°, 20.49°, 22.34°, 24.76°, 26.24°, and 29.77° in Figure 4, indicating that DOX has a crystalline nature. The DOX-loaded PASB hydrogel showed XRD patterns similar to those of pure PASB hydrogel (amorphous nature) along with a few peaks of DOX. While the characteristic peaks of DOX have

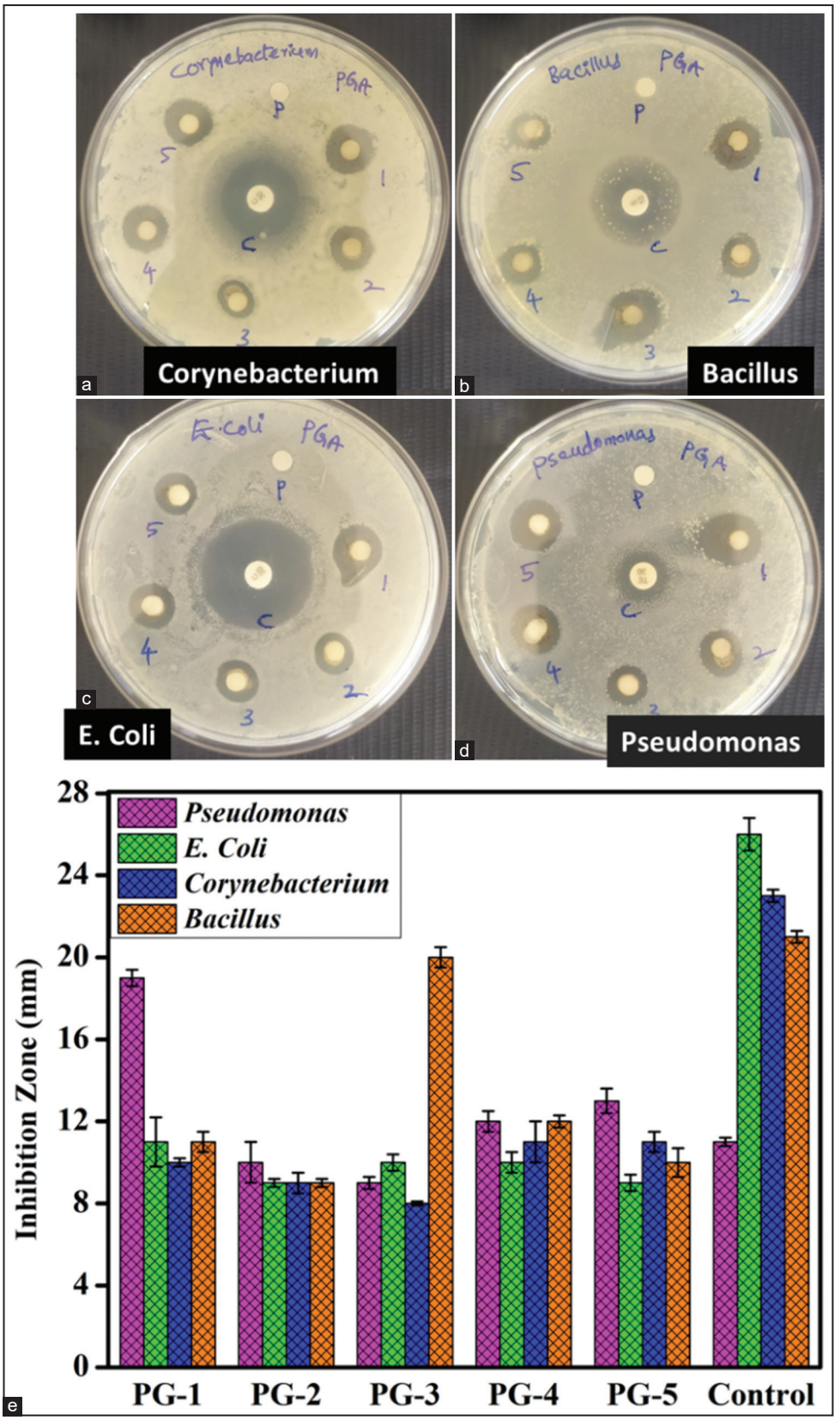



**Figure 8:** Antibacterial efficacy of PASB-silver nanocomposite hydrogels against (a) *Corynebacterium*, (b) *Bacillus*, (c) *Escherichia coli*, (d) *Pseudomonas aeruginosa,* and (e) comparison with the control.

diminished for DOX-loaded PASB hydrogel compared to pristine DOX, these results indicate that DOX is successfully capsulated in the hydrogel matrix. XRD peaks of Ag nanocomposite in PASB hydrogel were observed at two theta values along with a plane at 38.68° (111), 44.05° (200), 68.91° (220), and 76.53° (311). These values suggest that the silver nanoparticles have a face-centered cubic structure and are crystalline in character [17].

### *3.4. SEM and EDAX Analysis*

SEM of pure PASB hydrogel and Ag nanocomposite PASB hydrogels are shown in Figure 5a and b, respectively. Pure hydrogels have a surface that is smooth and nonporous, while the surface of Ag nanocomposite hydrogels is rough and homogeneous. Pure hydrogels are characterized by their lack of pores. According to the findings, silver nanoparticles are generated not only inside the matrix of the hydrogel but also on the surface of the hydrogel. This is evidenced by the EDAX spectrum that significant peak of silver is appeared at 3.0 keV.

### *3.5. Swelling Studies, Encapsulation Efficiency, and Drug Delivery of the Hydrogels*

Figure 6 show the swelling kinetics of all compositions of PASB hydrogels. The equilibrium swelling absorption method was used to study the DOX encapsulation into the polymer composites. Table 1 provides the chemical quantities, equilibrium SR, and encapsulation efficiency of each PASB hydrogels. Depending on the specific hydrogel, the DOX encapsulation efficiency can range from 40.32 ± 1.3 to 74.02 ± 0.8. The composition of the hydrogel influences the encapsulation efficiency, including the amounts of monomer and cross-linker. The chemotherapeutic agent DOX was effectively encapsulated into PASB hydrogels. To understand the stimuli-responsive behavior of the hydrogels, their *in vitro* drug delivery capability was tested in varied pH (1.2 and 7.4) and temperatures (25 and 37°C). More specifically, DOX drug release experiments were conducted in two different pH ranges i.e., 1.2 (the simulated gastric region) and 7.4 (the simulated intestinal region). Figure 7 shows that at pH 1.2, PASB-3 hydrogel had a greater DOX release.

### *3.6. Antimicrobial Application*

*A. Cherimoya* leaf extract was used to employ the green reduction process, resulting in the efficient incorporation of Ag nanoparticles into the PASB hydrogel matrix. This composite material exhibited remarkable antibacterial efficacy against various microbes (Figure 8). The zones of inhibition for *Corynebacterium*, *Bacillus*, *E. coli*, and *P. aeruginosa* ranged from 8 mm to 11 mm, 9 mm to 20 mm, 9 mm to 11 mm, and 9 mm to 19 mm, respectively. The PASB-Ag nanocomposite hydrogels exhibit antibacterial activity due to the electrostatic repulsion between positively charged silver ions and the negatively charged cell membranes of microorganisms. Researchers have elucidated the antibacterial action of AgNPs against bacteria through alterations in membrane permeability, respiration, intracellular adenosine triphosphate (ATP) levels, unregulated cellular motility, ATP depletion, and disruption of DNA replication. Cellular and metabolic processes rely on the expression of many proteins and enzymes to fulfill their important tasks.

## 4. CONCLUSION

Hydrogels have significant economic potential and are promising for several therapeutic applications, especially in the fields of drug delivery and wound healing. This work aims to tackle this difficulty by specifically examining propylene glycol alginate-co-poly (acrylamide) (PASB), which is a copolymer created using a simple free radical polymerization procedure utilizing potassium persulfate as a cross-linking agent. Furthermore, the aqueous leaf extract of *A. Cherimoya* acts as a reducing agent to generate silver nanoparticles (PASB-Ag) inside PASB hydrogels using an environmentally friendly approach. The characterization of PASB and PASB-Ag hydrogels was conducted utilizing many methods, such as FTIR, UV-vis, XRD, SEM, and EDAX. The findings indicate the effective containment of the anti-cancer medicine DOX inside PASB hydrogels, resulting in a substantial elevation in drug concentration. The promise of these hydrogels for controlled drug release applications is further validated by conducting *in vitro* cumulative drug delivery studies under various pH conditions and temperatures. The present work emphasizes the favorable characteristics of PASB hydrogels and their capacity to serve as drug delivery systems, thereby opening up opportunities for more investigation and advancement in drug delivery field.

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