SWELLING CHARACTERISTICS OF POLLYSACCHARIDE HYDROGEL AND THEIR POTENTIAL FOR DRUG DELIVERY

A PROJECT WORK

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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Submitted by:
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CANDIDATE'S DECLARATION

I, Charu Sharma (2K22/MSCCHE/06) student of MSc Chemistry, hereby declare that the project Dissertation titled "Swelling Characteristics of Polysaccharide Hydrogel and their potential for Delivery Drug" which is submitted by meto the Department of Applied Chemistry, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Science is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation title "Swelling Characteristics of Polysaccharide Hydrogel and their Potential for Drug Delivery" which is submitted by Charu Sharma (2K22/MSCCHE/06), Department of Applied Chemistry, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Science, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi **Prof. Roli Purwar**

Date: 06/06/2024 **(Supervisor)**

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Charu Sharma

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ABSTRACT

Using neem gum (NG) powder, polyethylene glycol (PEG) with molecular weights of 1500 and 6000, ammonium persulfate (APS) and acetic acid (AAc), the current study successfully synthesised and characterised a hydrogel, followed by the loading of levofloxacin. In order to optimise the hydrogel, different amounts of PEG, AAc, and APS were added and the swelling characteristics of NG and MOG hydrogels were investigated. For thorough characterisation, Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR-FTIR) was utilised which is used for identifying chemical functional groups present in the sample. The study examined the produced hydrogel's swelling behaviour and drug release kinetics in a range of pH settings, including distilled water and buffer solutions with a pH of 5.5, 7.4, and 8.5. This project advances the rapidly developing field of hydrogel production by demonstrating the feasibility of combining synthetic materials like PEG and AAc with natural polymers like NG. The process of customised optimisation clarifies the crucial function of essential components in regulating the characteristics of the hydrogel, including its rate of drug release and swelling. These developments could find use in medication delivery systems, where pH responsiveness is frequently a crucial component of successful treatment outcomes.

Keywords Neem Gum, Levofloxacin, Swelling, Drug Delivery, Moringa Oleifera Gum

Graphical Abstract

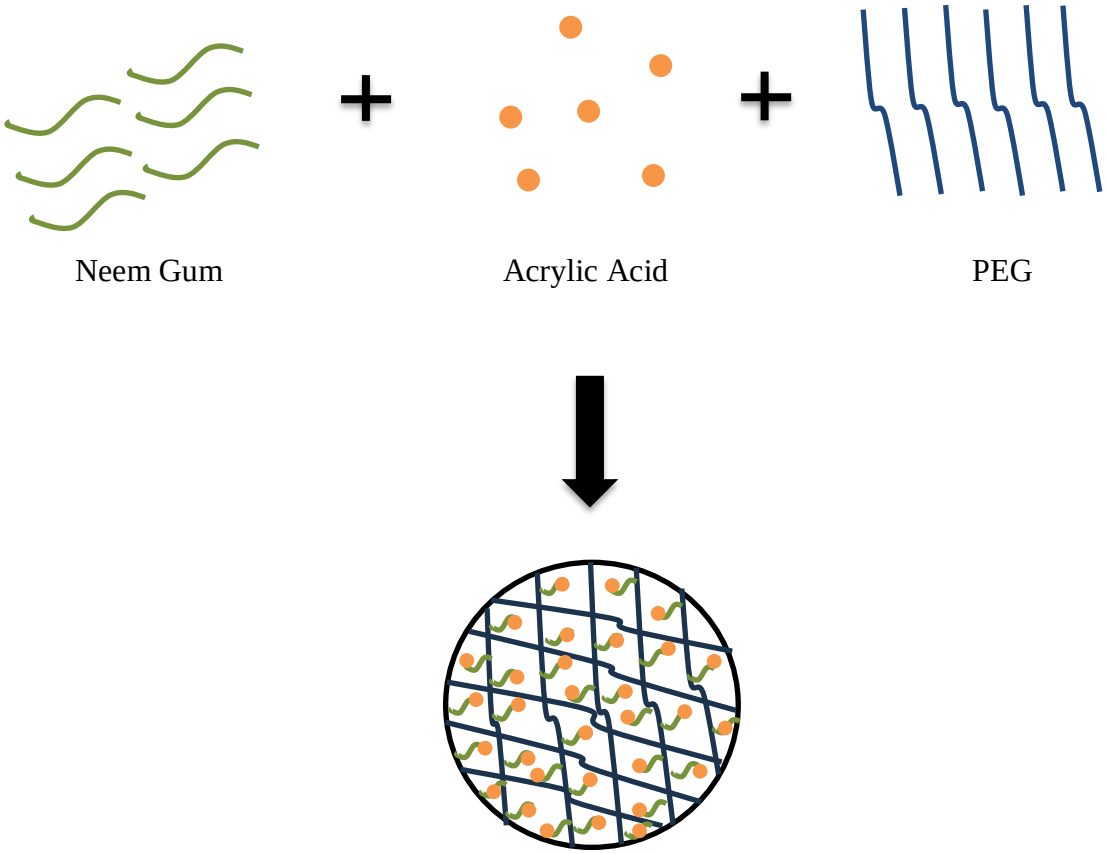

Fig1: Cross linked network formation

A process known as cross-linking occurs when neem gum, acrylic acid, and PEG (polyethylene glycol) are mixed together to create a network structure. Through the chemical process of cross-linking, polymer chains are joined to create a three-dimensional network structure. In this instance, the PEG and neem gum molecules are cross-linked by the acrylic acid. Polyacrylic acid (PAA), a polymer with numerous commercial uses, can be created by polymerizing acrylic acid, a monomer. Since acrylic acid is so reactive, it can join forces with other molecules to form bonds. PEG is a synthetic polymer that is frequently utilised in cross-linking processes because of its biocompatibility and capacity to make links with other molecules.

Neem gum and PEG molecules' hydroxyl groups react with acrylic acid molecules. The polymer chains are joined by covalent bonds created by this reaction, forming a network structure. As a result of these linkages forming, a gel-like substance with increased mechanical strength and stability is created. The resulting cross-linked network has unique properties such as increased viscosity, improved adhesion, and resistance to degradation. These properties make the material suitable for various applications such as drug delivery systems, tissue engineering, and controlled release formulations.

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List of Abbrevations

1. Neem Gum	NG
2. Acrylic Acid	AAc
3. Ammonium Persulfate	APS
4. Polyethylene Glycol	PEG
5. Moringa Oleifera Gum	MOG
6. Hydrogels	HGs

CHAPTER 1
INTRODUCTION

1.1 History

Wichterle and Lim created hydrogels for biomedical uses in the early 1960s by creating a network of hydrophilic poly (2-hydroxyethyl methacrylate) polymers through crosslinking, which allowed them to build contact lenses. Hydrogels have been the subject of countless research projects and technological advancements throughout the years, greatly influencing the biomedical and pharmaceutical industries. Three- dimensional polymeric networks that have a high capacity to absorb aqueous or biological fluids known as hydrogels. These structure's capacity to absorb water is due to the presence of hydrophilic groups like -OH, -CONH2, and -SO3H. Because of their high content, low adhesion strength to water or biological fluids, and smooth and porous nature, these polymeric networks bear a striking resemblance to living tissues. A hydrogel's water content plays a critical role in defining its unique physicochemical characteristics. In watery conditions, hydrogels do not dissolve but swell when absorbing water because of the necessary cross-links in their structure.

1.2 Objectives

Hydrogels that respond to a range of physical and chemical stimuli, including light, temperature, and pH, are referred to as "stimuli-sensitive hydrogels". Of these, pH shows the most promise for improving hydrogel's ability to swell. Anionic or cationic hydrogels are both capable of responding to pH. At pH values higher than their pka, anionic hydrogels ionize at pH. In gastrointestinal drug delivery system, anionic pH- responsive hydrogels are used to shield pharmaceuticals against inactivation and degradation in the environment while also facilitating their release at certain target areas. Because they offer a flexible substrate for regulated and targeted drug distribution, hydrogels are important components of drug delivery systems that enhance the effectiveness and safety of therapeutic interventions. Their distinct characteristics render them auspicious contenders for an extensive array of biomedical uses, encompassing tissue engineering, regenerative medicine, and cancer treatment. Drug can be encapsulated within the network structure of hydrogels. Chemical conjugation, physical entrapment, or the incorporation of drug-loaded nanoparticles into the hydrogel matrix are the three methods available for loading drugs into hydrogels. This encapsulation permits regulated release kinetics while shielding medications from deterioration.

Hydrogels can be designed to deliver drugs to particular body tissues or cells on demand. Drugs can be delivered to diseased tissues specifically by functionalizing hydrogels with ligands or antibodies that can bind to specific cell surface receptors. This minimises systemic exposure and off-target effects. Organic biopolymers, such as polysaccharides, are extensively used and appreciated for their significant functions in various physiological and medicinal domains. Pharmaceutical formulations prefer biopolymers because of their low toxicity, biocompatibility, and biodegradable nature. Today, hydrogels stand as versatile materials poised to revolutionize healthcare, biotechnology, and environmental science

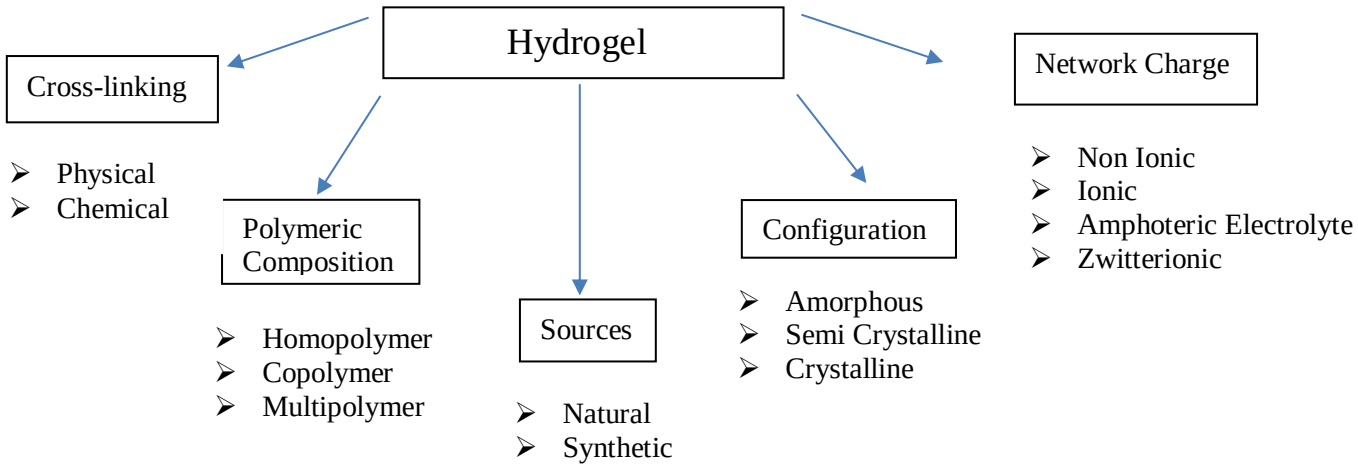
CHAPTER 2
LITERATURE REVIEW

2.1 Hydrogels: Definition and Properties

Hydrogels are three- dimensional, hydrophilic polymer networks capable of absorbing and retaining large amounts of water and or biological fluids while maintaining their structural integrity. The polymer chains in hydrogels are interconnected through covalent or physical cross links, providing mechanical strength and stability to the gel structure. The most prominent properties of hydrogel is their ability to swell in the presence of water or other biological fluids, this swelling behaviour is the result of the hydrophilic nature of the polymer chains and the osmotic pressure created by the adsorbed water. The swelling behaviour of the hydrogels can be controlled by adjusting the factors such as composition of the polymer networks, crosslinking density and environmental conditions such as pH, temperature. They are non-toxic and hence suitable for various applications such drug delivery, wound healing. They are typically soft materials that can resemble those of natural tissues. They can exhibit responses to the external stimuli such as changes in temperature, pH or the presence of specific ions. Hydrogels can be synthesised from various natural and synthetic polymers. Examples of common polymers used in the hydrogel synthesis include poly (ethylene glycol), poly (vinyl alcohol), poly (acrylic acid), and natural polymers like alginate, chitosan.

2.1.1 Different criteria for classifying hydrogel

Hydrogels can be categorised in a number of ways, such as (i) by synthesis method, (ii) by kind of monomer or polymer used, and (iii) by ionic charge.



Based on the technique of synthesis, polysaccharide HGs are split into two subtypes:

(a) Physically (reversible) crosslinked hydrogels
(b) Chemically (permanent) crosslinked hydrogels

Two categories of hydrogel can be distinguished based on their origins-

(a) Natural- Polypeptide based (such as gelatin, collagen) and polysaccharide-based (such as cellulose, starch, alginate, and agarose)
(b) Synthetic- Petrochemical-based (such as polyacrylic acid, methacrylic acid, vinyl acetate, and polyethylene glycol)

Based on the electric charge presence or absence or absence in the cross-linked chains, four classification can be used to describe different HGs

(a) Ionic (anionic and cationic)
(b) Non-ionic
(c) Zwitterionic (Each repeating unit contains both positively charged and negatively charged ions)
(d) Amphoteric electrolyte (both acidic and basic groups)

Depending on their polymeric composition, HGs can be divided into three types:

(a) Homopolymer- A single kind of monomer, known as a homopolymer, is employed to create the HGs polymeric web network
(b) Copolymer- Copolymeric refers to a 3D network that has a minimum of two distinct monomer units and a minimum of one hydrophilic component
(c) Multipolymer- An HGs network arrangement holds the two synthetic or natural macromolecules that are individually cross-linked and compromise multipolymer interpenetrating hydrogels made od polymers together.

Depending on configuration

(a) Crystalline
(b) Semi-crystalline
(c) Amorphous

2.2. Neem Gum and its properties

Neem gum is a natural exudate obtained from the bark of the neem tree, scientifically known as *Azadirachta indica*. This tree is native to the Indian subcontinent and has been revered for its various medicinal properties for centuries. It is primarily composed of polysaccharides, which are long chains of sugar molecules, harvested by tapping the bark of the neem tree, in the same manner as rubber is harvested from rubber plants. Making cuts in the bark to let the gum escape is part of the extraction procedure. High molecular weight polysaccharides, in particular, make up the majority of the ingredients in neem gum. The sticky and binding qualities of neem gum are derived from these

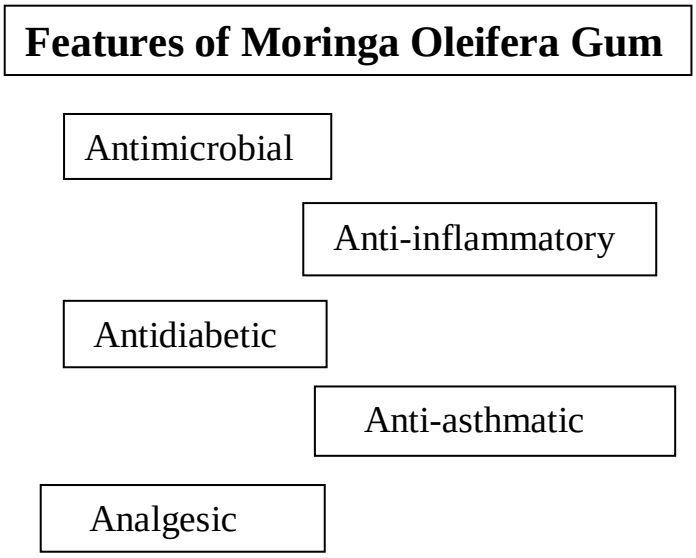
polysaccharides. Neem gum is well-known for having outstanding adhesive qualities, which enable it to be used in a variety of industries, including the food, cosmetic, and pharmaceutical ones. It can be utilised as a natural adhesive in goods like herbal cosmetics and toothpaste, as well as in the manufacturing of conventional medications. Bioactive substances including tannins, flavonoids, and terpenoids are responsible for the antibacterial qualities of neem gum. It is advantageous in oral care products because of these qualities, which help with dental health maintenance and issue prevention. Neem gum may be helpful in treating a variety of inflammatory problems, such as gum disease and oral inflammation, as some research have suggested that it has anti-inflammatory properties.

Because neem gum has mucoadhesive qualities, it can stick to mucosal surfaces. This property improves the residence time and drug absorption at the site of action, which is beneficial for drug delivery systems that target mucosal tissues like the gastrointestinal tract, nasal passages, or ocular surfaces. Neem gum has inherent hydrophilic properties, meaning it readily absorbs water. This characteristic makes it ideal for creating hydrogels with high swelling capacity. When hydrated, neem gum-based hydrogels can swell to several times their dry weight, forming a soft and gel-like matrix capable of absorbing and retaining large amounts of fluid. Neem gum's swollen behaviour has advantages for applications involving wound healing. A dressing based on neem gum can be placed to wounds to absorb excess exudate and keep the area wet, which promotes healing. In addition to limiting microbial contamination and fostering tissue regeneration, the hydrogel's swelling action aids in the creation of a protective barrier over the wound.

Fig2: Features of Neem Gum

2.3 Properties of Moringa Oleifera gum

The adaptable plant moringa oleifera is well-known for its several therapeutic, dietary, and industrial uses. Known by many as the "drumstick tree" or just "moringa," this plant is indigenous to the Indian subcontinent but is now grown in many tropical and subtropical areas across the world because of its adaptability to a variety of soil types and climates. The plant is prized for its beneficial minerals, antioxidants, and bioactive chemicals found in its leaves, pods, seeds, and flowers. Moringa leaves, for instance, are a valuable dietary supplement, particularly in areas where malnutrition is common, because they are a great source of vitamins, minerals (including calcium, potassium, and iron), and protein. The potential of moringa in numerous scientific and industrial applications, such as the creation of hydrogels, has also been investigated recently by researchers. Hydrogels are composed of hydrophilic polymers arranged in three dimensions that retain their structural integrity even when a significant amount of water is absorbed. They are widely used in environmental engineering, agriculture, food science, and biomedicine. Hydrogel matrices with desired properties are produced using moringa-based hydrogels by utilising the special qualities of components obtained from moringa, such as proteins, polysaccharides, and bioactive substances. These hydrogels may be used in drug delivery, wound healing, tissue engineering, diagnostic devices, and other biomedical applications due to their potential for biocompatibility, biodegradability, antibacterial qualities, and the release of bioactive compounds. Bioactive ingredients from moringa leaves, seeds, or other plant parts are usually extracted and added to hydrogel formulations using chemical or physical crosslinking techniques. This is how moringa-based hydrogels are made. To improve the mechanical strength, swelling behaviour, drug release kinetics, and biocompatibility of these hydrogels for particular uses, researchers have experimented with various formulations and approaches. All things considered, moringa oleifera exhibits great potential as a flexible and sustainable resource for the creation of hydrogels with a wide range of uses in the industrial and biological domains. By utilising this plant's special qualities, scientists are able to find new and creative approaches to solving problems and enhancing human health and wellbeing.



2.4 Polyethylene Glycol

Polyethylene glycol is a multifaceted polymer renowned for its remarkable properties across a spectrum of applications, owing to its unique chemical structure and behaviour. As a hydrophilic compound PEG exhibits a strong affinity for water, enabling easy dissolution in aqueous solutions. This property forms the cornerstone of its utility in diverse fields. One of the most notable attributes of PEG is its biocompatibility and low toxicity profile. These characteristics are paramount in biomedical systems. More over its low toxicity ensures safety in pharmaceutical formulations. PEG's hygroscopic nature is another salient feature contributing to its utility in various applications. Chemically, PEG is composed of repeating ethylene oxide units ($-CH_2CH_2O-$) and is available in a range of molecular weights, which significantly influences its physical and chemical properties. Lower molecular weight PEGs (200-600) are viscous liquids, while higher molecular weight PEGs (8000 and above) are waxy solids or powders.

2.5 Hydrogel Synthesis Method

Hydrogels are synthesized using a variety of methods which can be broadly classified into two categories:

- **Physical cross linking**

  In this, the polymer chains are held together by weak interactions such as hydrogen bonding, ionic interactions, or hydrophobic interactions. These hydrogels are typically weaker and more sensitive to changes in environmental conditions than chemically crosslinked hydrogels.

  1. Hydrogen bonding:

  It is a common mechanism for physical crosslinking in hydrogels made from natural polymers. Such as alginate and chitosan. In these hydrogels, the hydroxyl groups on the polymer chains form hydrogen bonds with each other, creating a physically crosslinked network.

  2. Ionic Interactions:

  Interactions cab be used to incorporating oppositely charges ions into the polymer charged ions into the polymer network. For example: alginate hydrogels can be crosslinked with calcium ions (Ca2+)

  3. Hydrophobic interactions:

  This can be used to crosslink hydrogels by incorporating hydrophobic groups into the polymer network. These hydrophobic groups will aggregate in water, creating a physically crosslinked network.

- **Chemical crosslinking:**

In chemical crosslinking, the polymer chains are covalently bonded to each other, creating a more permanent and stable hydrogel network. Chemical crosslinking can be achieved using variety of methods including:

1. **Free radical polymerization**:

It is a common method for chemically crosslinking synthetic hydrogels. In this method, free radicals are generated to initiate the polymerization of monomers, which then react with each other to form a crosslinked network.

a) **Initiation**- This is the first step where free radicals are generated. These free radicals are highly reactive species with unpaired electrons. The initiation can be done through various methods

Thermal decomposition- Heat cause the decomposition of initiators like benzoyl peroxide generating free radicals.

Photoinitiation- Light (usually UV) induces the decomposition of photo initiators, generating free radicals

Propagation- Once free radicals are generated, they react with monomer molecules to form new radicals. This reaction continues, leading to the growth of the polymer chain.

b) **Crosslinking**- for hydrogel formation cross linkers are used they are multifunctional monomers that can react at multiple sites, linking different polymer chains together to form a network structure. As the polymer chains grow, the crosslinker molecule incorporate into the chains, creating a three-dimensional network. This crosslinked network is essential for hydrogel properties as it allows the material to swell and retain large amounts of water without dissolving.

c) **Termination**- The polymerisation process eventually terminates, stopping the growth of the polymer chain.

2. **Enzymatic crosslinking:**

It is a method for crosslinking hydrogels using enzymes. Enzymes are highly selective catalysts that can be used to form specific types of crosslinks between polymer chains. The choice of hydrogel synthesis method depends on the desired properties of the final hydrogel. For example: if a strong and stable hydrogel is needed, then chemical crosslinking would be preferred method. If on the other hand a self-healing hydrogel is needed, then physical crosslinking would be a better option

2.6 Challenges and limitations

The characteristics and performance of hydrogels may vary as a result of this diversity. Because neem gum is not very soluble in water, creating hydrogels with the right characteristics can be difficult. To increase its solubility, more processing stages or the addition of co-solvents would be necessary. Hydrogels made from neem gum could not be as mechanically strong as hydrogels made from other natural polymers or manufactured hydrogels. This may have an impact on their stability and appropriateness for particular uses, particularly those that call for durability or mechanical strength. The stability, effectiveness, or release profile of neem gum or its breakdown products within the hydrogel matrix may be impacted by medication interactions. Testing for compatibility is essential to determine whether neem gum is appropriate for a given drug delivery application. The economic feasibility of employing neem gum in hydrogel synthesis and drug delivery systems may be impacted by the scalability of neem gum extraction and purification procedures, which may be a barrier to large-scale production.

2.7Applications

Hydrogels can be designed to release at a predetermined rate. This controlled release can improve drug efficacy and minimise the side effects by ensuring a steady concentration of the drug in the body. Incorporating specific molecules into the hydrogel structure it will be easy to target the delivery of drugs to specific tissues and organs. This targeted approach can further enhance the therapeutic benefits and reduce the impact on healthy cells. These hydrogels can potentially serve as scaffolds for tissue engineering applications. Their biocompatible nature allows for cell attachment and growth, promoting tissue regeneration. The hydrogel can be loaded with nutrients or pesticides and used in agriculture. The slow release of these compounds from the hydrogel can improve efficacy and minimise environmental impact compared to traditional methods. The high water retention capacity of hydrogels can be beneficial in dry or arid region. By incorporating them into soils the water retention capacity of the dry soli can be improved and reduce the need of frequent irrigation

CHAPTER 3
MATERIALS AND METHODS

3.1 Materials

Acrylic Acid (AAc) [Moly Chem], Ammonium Persulfate (APS) [Sigma-Aldrich], Poly ethylene Glycol (Mol wt. 1500 and 6000], and Hydrogel of MOG, Neem gum powder, Distilled Water, Levofloxacin (Antibiotic)

3.2 Synthesis of Neem Gum (NG) based poly ethylene glycol (PEG) Hydrogel

The hydrogel based on NG were fabricated by free radical polymerization with APS as the initiator. This reaction procedure was conducted by combining Acrylic Acid and Distilled Water. The desired amount of NG was poured into the mixture and then stirred. Then a determined amount of APS and PEG was introduced and magnetically stirred. After that resultant solution was poured into the test tubes and placed in a hot water bath at 60^{o}C. The hydrogels were recovered from the test tube and sliced. The hydrogel slices were then left to dry in the oven at 50^{o}C till completely dried. The complete process is described as follows:

Preparation of Neem Gum Solution

100ml of distilled water with 2g of neem gum was poured. To optimize dissolving, the beaker was placed on a magnetic stirrer for a full day to prepare a solution of neem gum.

Addition of Acrylic Acid

After dividing the neem gum solution into two 10ml beakers, each beaker was filled with 3ml of acrylic acid and distilled water. The mixture was then stirred for thirty minutes using a magnetic stirrer.

Crosslinking Reaction

0.08 gm of APS were added to the mixture after 30 minutes, and it was left to agitate for an additional hour. The APS started the process of creating the hydrogel network and crosslinking the molecules of acrylic acid.

Preparation of PEG solution

For two more hours, the liquid in each beaker was combined with 0.5 gm of PEG (which had molecular weights of 1500 and 6000). Hydrogel was created as a result of the whole mixture.

Gelation

Two test tubes were filled with the beaker solution. The test tubes were submerged in a water bath that was heated to 60°C until gelation occurred. The gelation duration may have varied due to changes in reactant concentration, temperature, and the presence of additives.

Washing and Drying

After the gelation process was complete, the hydrogel was thoroughly cleaned to remove any unreacted initiators, monomers, or by-products. The final neem gum-based hydrogel product was then obtained by thinly slicing it and drying it at 50°C. It takes roughly three to four days for this process to be finished drying.

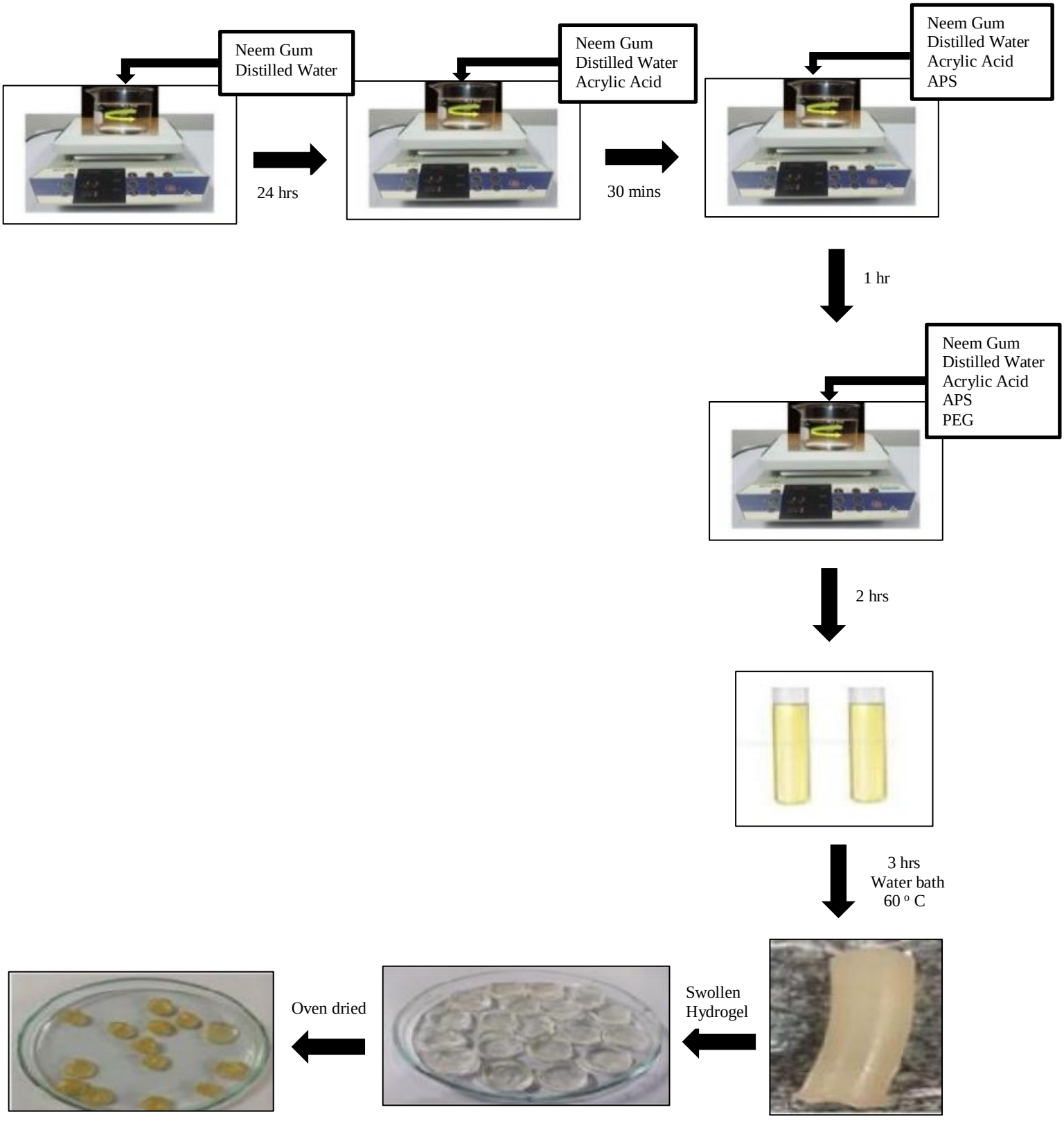


Fig3: Representation of hydrogel formation

3.3 Swelling Characteristics

The hydrogel matrix hydrates when it comes into touch with water and buffer solution, allowing the molecules to enter the polymer chains. As a result, the network widens and the spacing between polymer chains increases. Osmotic pressure increases within the network as more solution diffuses into the hydrogel. As a result, the hydrogel continues to inflate until it reaches equilibrium, at which point the rate of absorption and loss is equal. The hydrogel samples' initial weight is precisely determined prior to swelling, the produced hydrogel samples are submerged in an appropriate solvent, frequently buffer solution or water. By periodically removing the hydrogel samples from the solvent, gently blotting excess surface liquid, and measuring their diameters, swelling kinetics are tracked over time. Final measures are done after enough time has passed, usually after swelling approaches equilibrium.

3.3.1 Process of Swelling of Hydrogel

After the hydrogel had completely dried, the beginning mass of each piece of dry hydrogel was precisely measured using an analytical weighing balance. The next step was to make a swelling medium, which was usually a buffer solution with a pH of 5.5, 7.4, 8.5 and distilled water. Every sample bag was weighed, and after carefully placing each component inside the bag, the total weight was noted. The swelling medium was then fully immersed in the hydrogel samples that had been pre-weighed. After allowing the hydrogel samples to swell for two hours at a steady pH and temperature, the weight of the enlarged hydrogel was noted.

3.4 Drug Delivery

Levofloxacin is carried in a matrix by the hydrogel. During the incubation phase, the drug molecules become trapped inside the hydrogel matrix. This encapsulation permits a gradual, regulated release of the medication while also shielding it from deterioration. Levofloxacin is absorbed by the hydrogel, which creates a reservoir for the medication. Gradually, when the hydrogel matrix expands and shrinks in response to external factors like pH and temperature, the medication is released from the hydrogel. The drug's therapeutic concentrations are maintained in the surrounding environment thanks to this controlled release mechanism. The stability and effectiveness of the medication depend on the pH level being kept constant, which is assisted by the use of buffer solution. You can guarantee that the drug stays in the intended form for optimum delivery by employing a buffer solution because pH fluctuations might impact the drug's solubility and bioavailability.

3.4.1 Process of Drug Delivery

Started by taking two beakers, each containing 500ml of distilled water. To each beaker 25mg of levofloxacin was added, a commonly used antibiotic. It is soluble in water, so it will dissolve in the solution inside the beakers, then kept the solution for 2 days. Next added two pieces of hydrogel into each beaker and allowed the solution to sit for 72 hours. During this time, the hydrogel will absorb some of the levofloxacin solution, incorporating the drug into its structure. This process is often referred to as loading or encapsulation. After 72

hours of incubation period added 2ml of buffer solution to each beaker. Buffer solutions are used to maintain a constant pH level, which is important for many biochemical processes, including drug release. Following the addition of the buffer solution, removed 2ml of the solution from each beaker. This process helps to maintain the equilibrium within the system. By removing a portion of the solution and replacing it with the buffer solution, it was ensured that the concentration of levofloxacin remains constant.

Fig4: Powder form of Levofloxacin

CHAPTER 4
RESULT AND DISCUSSION

Table1: The proportion of reactants used in hydrogel formation

Sample Code	Neem Gum (gm)	Acrylic Acid (ml)	APS (gm)	PEG (gm)	
				15000	6000
S-1	2	3	0.5	0.3	0.3
S-2	2	3	0.1	0.3	0.3
S-3	2	3	0.03	0.3	0.3
S-4	2	3	0.01	0.5	0.5
S-5	2	3	0.03	0.5	0.5
S-6	2	3	0.05	0.5	0.5
S-7	**2**	**3**	**0.08**	**0.5**	**0.5**
S-8	2	3	0.08	0.8	0.8
S-9	2	3	0.08	1.5	1.5
S-10	2	3	0.1	1	1
S-11	2	6	0.08	0.8	0.8
S-12	2	6	0.08	0.8	0.8
S-13	2	6	0.5	0.8	0.4
S-14	2	6	0.8	1	0

Fig5: Gel containing PEG 6000

Fig6: Gel containing PEG 1500

Table2: Weight of sample bag and dry hydrogel for MOG (1500)

Serial no.	Buffer solution	Weight of empty sample bag	Weight of dried hydrogel piece	Total weight of the sample
1	5.5	0.358	0.363	0.721
2	7.4	0.323	0.377	0.700
3	8.5	0.260	0.390	0.650
4	Dis H2O	0.397	0.340	0.737

Table3: Weight of sample bag and dry hydrogel for MOG (6000)

Serial no.	Buffer solution	Weight of empty sample bag	Weight of dried hydrogel piece	Total weight of the sample
1	5.5	0.364	0.399	0.763
2	7.4	0.372	0.330	0.702
3	8.5	0.390	0.402	0.792
4	Dis H2O	0.371	0.356	0.727

Table4: Weight of sample bag and dry hydrogel for NG (1500)

Serial no.	Buffer solution	Weight of empty sample bag	Weight of dried hydrogel piece	Total weight of the sample
1	5.5	0.237	0.376	0.613
2	7.4	0.307	0.364	0.671
3	8.5	0.368	0.386	0.754
4	Dis H2O	0.136	0.405	0.541

Table5: Weight of sample bag and dry hydrogel for NG (6000)

Serial no.	Buffer solution	Weight of empty sample bag	Weight of dried hydrogel piece	Total weight of the sample
1	5.5	0.419	0.457	0.876
2	7.4	0.355	0.530	0.885
3	8.5	0.385	0.524	0.909
4	Dis H2O	0.352	0.533	0.885

At a constant pH and temperature, the hydrogel samples were permitted to swell. The swelled hydrogel samples were carefully extracted from the swelling media at every two-hour interval. The samples were weighed again to determine their swollen masses after any remaining surface water was wiped off of them using tissue paper.

Table6: Weight measurement of swollen hydrogel at every 2hr for MOG (1500)

Dry Wt.	1^{st} reading	2^{nd} reading	3^{rd} reading	4^{th} reading	5^{th} reading	6^{th} reading	7^{th} reading	8^{th} reading	9^{th} reading	10^{th} reading	11^{th} reading	12^{th} reading
0.721	1.606	2.262	2.180	2.803	2.830	2.783	3.334	2.955	4.262	3.716	4.004	3.986
0.700	2.390	2.628	2.335	3.627	4.078	5.241	5.004	5.508	5.702	5.462	5.685	5.485
0.650	3.344	3.861	4.778	7.362	6.363	7.100	7.258	6.059	6.545	6.589	7.546	6.370
0.737	2.386	3.115	3.159	2.547	3.120	2.822	2.781	2.423	2.435	3.205	3.440	3.009

Table7: Weight measurement of swollen hydrogel at every 2hr for MOG (6000)

Dry Wt.	1st reading	2nd reading	3rd reading	4th reading	5th reading	6th reading	7th reading	8th reading	9th reading	10th reading	11th reading	12th reading
0.763	2.519	1.825	1.902	2.844	3.242	3.536	3.336	3.171	4.439	4.474	4.851	4.637
0.702	2.349	2.306	3.002	3.371	3.892	4.465	5.012	4.501	5.707	5.217	4.909	5.559
0.792	2.964	3.428	4.245	6.676	7.539	6.469	7.231	6.566	7.064	7.550	7.492	7.293
0.727	2.460	2.665	3.404	2.887	2.676	2.853	2.303	2.581	3.146	3.035	3.085	3.136

Table8: Weight measurement of swollen hydrogel at every 2hr for NG (1500)

Dry Wt.	1st reading	2nd reading	3rd reading	4th reading	5th reading	6th reading	7th reading	8th reading	9th reading	10th reading	11th reading	12th reading
0.163	2.236	2.193	2.489	3.344	2.700	3.096	3.845	3.706	5.232	5.498	6.046	5.597
0.671	2.421	2.851	2.685	3.506	3.680	5.008	5.844	5.393	6.498	6.083	7.086	6.959
0.754	2.841	2.612	3.125	6.856	6.078	7.400	6.908	6.906	7.160	7.430	7.683	7.213
0.541	1.573	1.627	1.741	1.948	1.633	1.712	1.787	1.871	2.456	2.491	2.211	2.153

Table9: Weight measurement of swollen hydrogel at every 2hr for NG (6000)

Dry Wt.	1st reading	2nd reading	3rd reading	4th reading	5th reading	6th reading	7th reading	8th reading	9th reading	10th reading	11th reading	12th reading
0.876	2.450	2.487	2.811	3.351	3.444	3.443	3.789	3.564	5.783	5.623	6.000	5.670
0.885	2.793	2.691	2.433	4.976	4.093	5.825	5.978	5.699	6.972	7.226	6.798	6.611
0.909	3.151	3.389	3.499	8.697	8.571	9.318	7.692	7.378	8.913	9.031	9.109	9.277
0.885	2.986	3.037	3.141	3.472	3.096	3.035	3.381	3.554	3.838	3.785	3.653	3.963

The following formula was used to calculate the swelling ratio, which is given as a percentage:

Swelling Ratio (%) = (Ws - Wd) / Wd

where Wd is the starting weight of the dry hydrogel and Ws is the weight of the swollen hydrogel

Table10: Swelling percentage of NG

pH5.5		pH7.4		**pH8.4**		Dis H2O	
PEG (1500)	PEG (6000)	PEG (1500)	PEG (6000)	**PEG (1500)**	PEG (6000)	PEG (1500)	PEG (6000)
568.6	589.3	780.4	870	**1576**	1567	2572	2473

Table11: Swelling percentage of MOG

pH5.5		pH7.4		**pH8.4**		Dis H2O	
PEG (1500)	PEG (6000)	PEG (1500)	PEG (6000)	**PEG (1500)**	PEG (6000)	PEG (1500)	PEG (6000)
1013	7033	1098	9472	**4311**	3860	3338	2381

ATR-FTIR

Fourier Transform Infrared (FTIR) spectroscopy is a technique used to obtain an infrared spectrum of absorption or emission of a solid, liquid, or gas. It determines the identity of an unknown substance, the proportion of each component in a combination, and the functional group of an organic compound. The theory guiding infrared spectroscopy states molecules have a tendency to absorb infrared area frequencies. Not all bonds inside a molecule absorb infrared light. Only those bonds are considered infrared active which can exhibit a change in their dipole moment. Polyethylene glycol (PEG) 1500 and 6000 are polymers that differ in their molecular weights, with PEG 1500 having a lower molecular weight compared to PEG 6000. When comparing the FTIR spectra of different molecular weights of polyethylene glycol (PEG), such as PEG 1500 and PEG 6000, there are a few key differences

1. O-H Stretching Region: Both PEG 1500 and PEG 6000 will have broad peaks in this region due to the presence of hydroxyl groups. However, the intensity might slightly differ due to the difference in the average number of hydroxyl end group, although this difference is often subtle.
2. C-H Stretching Region: The peaks associated with the C-H stretching vibrations (symmetric and asymmetric) will be present in both spectra. The intensities of these peaks might differ slightly due to the different chain lengths.
3. C-O-C Stretching and Bending Region: This region will show peaks associated with the ether (C-O-C) linkages. Both PEG 1500 and PEG 6000 will have similar peak positions, but the relative intensities might differ due the different polymer chain lengths.

The overall shape of the spectra will be quite similar since both polymers are chemically very similar, differing primarily in the length of their polymer chains. The larger molecular weight of PEG means it has a longer polymer chain, which could lead to minor shifts in peak intensities or broadening due to increased intramolecular interactions and changes in the overall conformation of the polymer chains.

Fig7: Perkin Elmer Two-Spectrum FTIR spectrometers

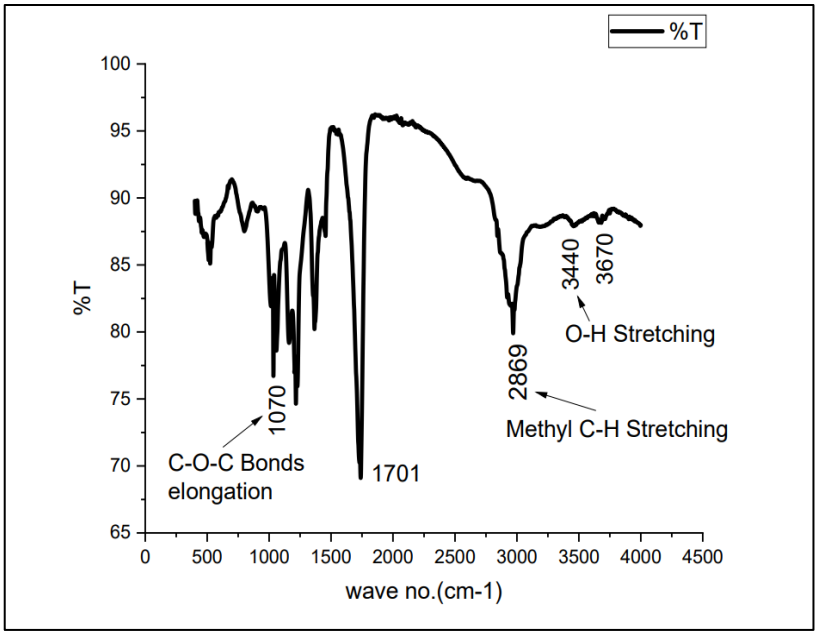


Fig8: ATR-FTIR of PEG 1500

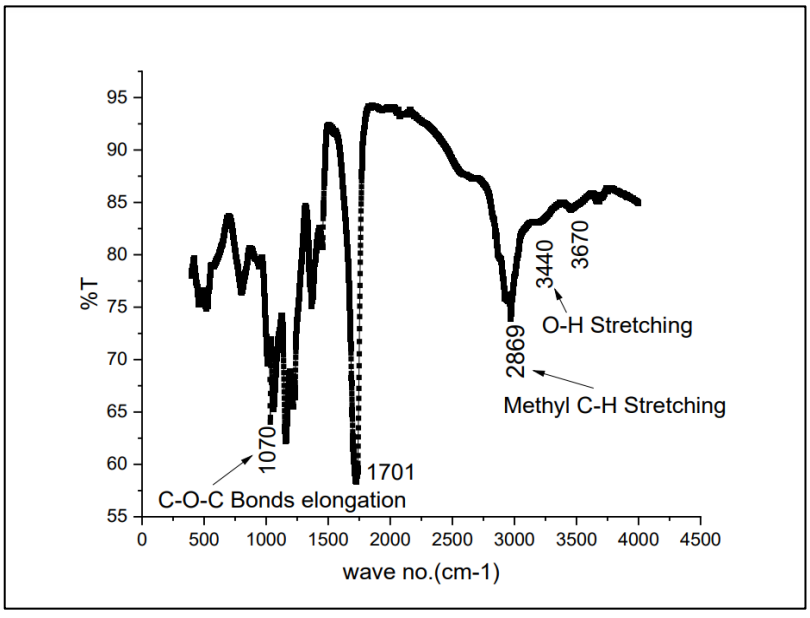


Fig9: ATR-FTIR of PEG 6000

Swelling Curve

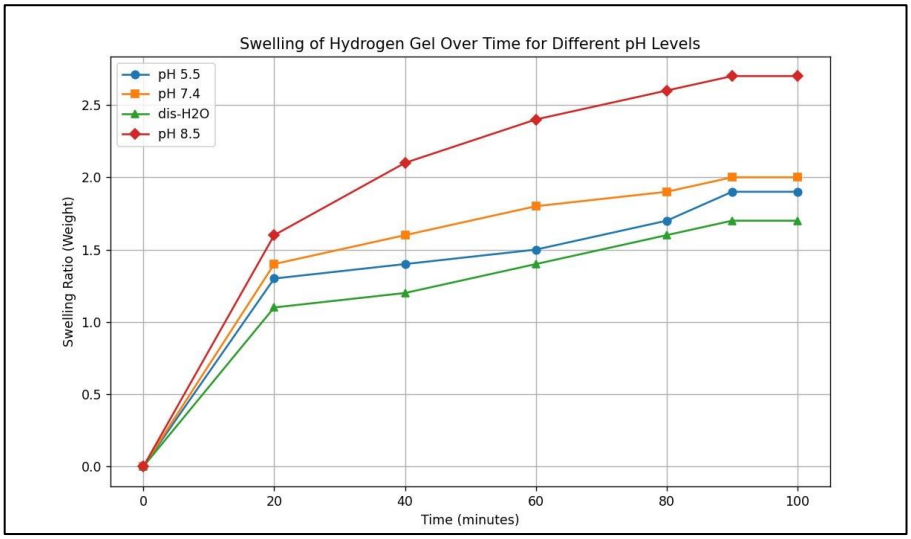


Fig10: Swelling Curve of NG Hydrogel at Different pH

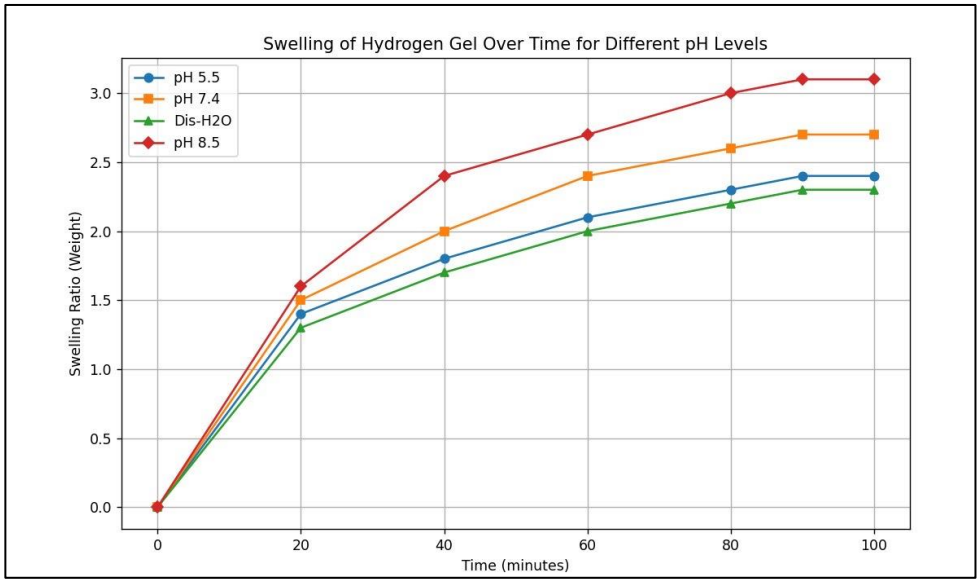


Fig11: Swelling Curve of MOG Hydrogel at Different pH

CHAPTER 5
CONCLUSION

This study explored a successful method for creating hydrogels using neem gum. This technique, based on a free radical mechanism, proved to be efficient in generating the desired hydrogels. It was able to control the synthesis process by adjusting the concentrations of ammonium persulfate (APS), polyethylene glycol (PEG), and acrylic acid. To analyze the structure of the synthesized hydrogel, a technique called attenuated total reflectance Fourier-transform infrared spectroscopy (ATR-FTIR) was employed. Furthermore, the investigation compared the water absorption properties of two hydrogels, neem gum (NG) and modified neem gum (MOG). The results were impressive, demonstrating a significant capacity for both NG and MOG hydrogels to absorb water. Additionally, these hydrogels displayed a promising sensitivity to external factors, particularly pH changes. Interestingly, the swelling capacity of the hydrogels was found to be significantly enhanced in alkaline environments (high pH). The potential of these hydrogels for drug delivery was also investigated Experiments were conducted to assess how the hydrogels released drugs at various pH levels.

CHAPTER 7
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CHAPTER 8

CONFERENCE ATTENTED

1. Presented my work at the International Conference on **"Current Trends in Chemical Sciences for Sustainable Living"** held at **Shyam Lal College, University of Delhi** on 4th April 2024.

SLC (University of Delhi)
SHYAM LAL COLLEGE
NAAC ACCREDITED A++ & NIRF 68th

International Conference
on
Current Trends in Chemical Sciences for Sustainable Living

Certificate

This is to certify that Prof./Dr./Mr./Ms. CHARU SHARMA
from Delhi Technological University has participated/ presented paper/poster/delivered Invited Lecture on Synthesis of Neem Gum based on Hydrogel in the "INTERNATIONAL CONFERENCE on CURRENT TRENDS IN CHEMICAL SCIENCES FOR SUSTAINABLE LIVING" organized by Department of Chemistry under the aegis of IQAC, Shyam Lal College, University of Delhi on 4-5th April 2024.

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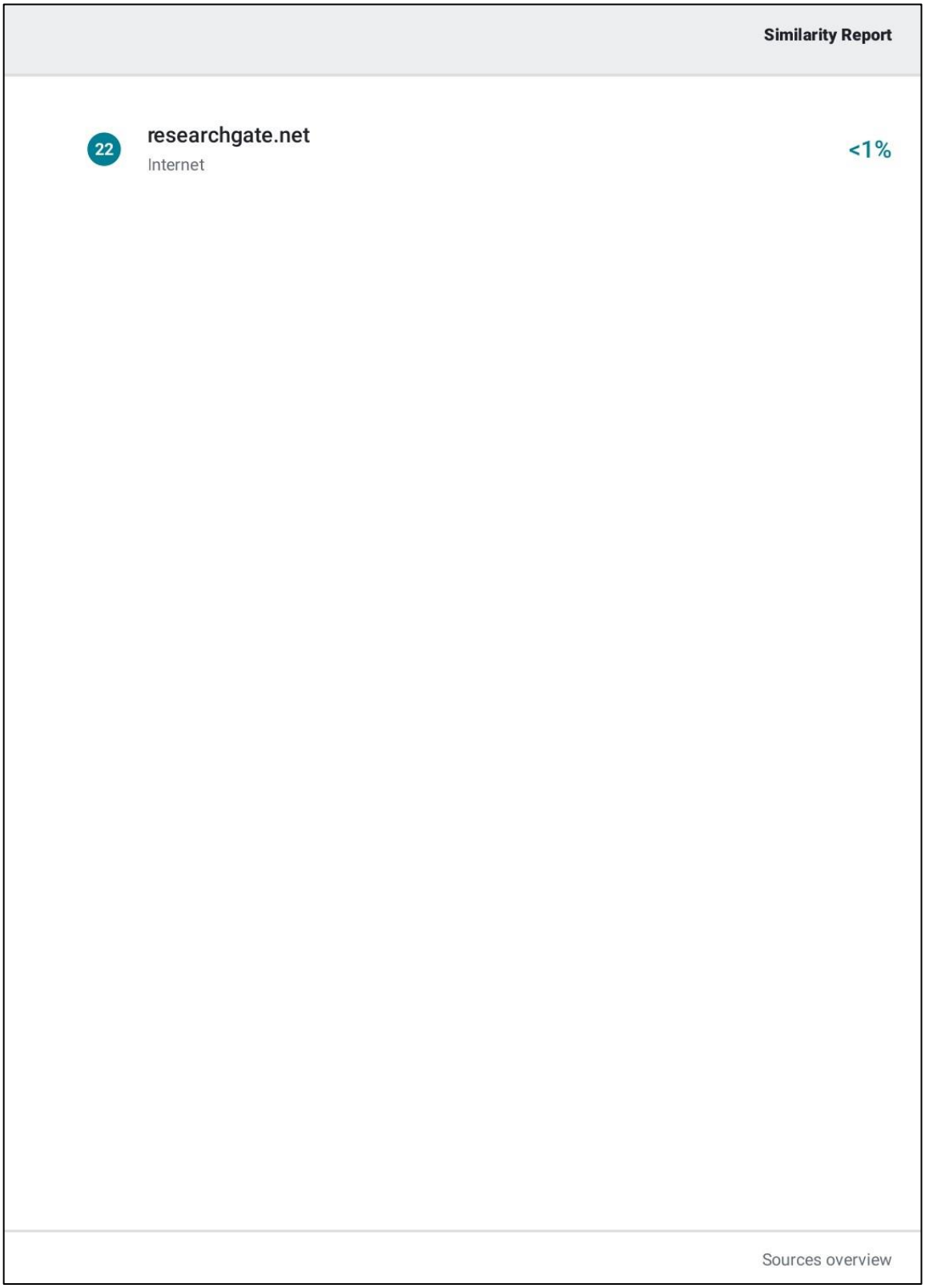
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