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Development and Evaluation of a Protective Topical gel against Metal Toxicity Produce by Cosmetic

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Abstract
The widespread use of cosmetic products has raised concerns about heavy metal exposure, which can lead to severe dermatological and systemic health issues. This study focuses on the development and evaluation of a protective topical gel formulated to minimize metal toxicity from cosmetics. A Carbopol 940-based gel was prepared incorporating disodium EDTA (a metal chelating agent), propylene glycol (a penetration enhancer), triethanolamine (a pH stabilizer), and cinnamon oil (an antimicrobial agent). The gel was evaluated for physicochemical properties, homogeneity, spreadability, viscosity, and stability. The optimized formulation (G2) exhibited excellent homogeneity, smooth texture, and a stable pH (6.88) and viscosity (20,800 cps) after three months of accelerated stability testing. The results suggest that the developed gel can effectively act as a protective barrier against heavy metal exposure from cosmetics, ensuring skin safety and long- term effectiveness.

Keywords: Gel, Heavy metal, Cosmetic, Chelating agent.

1] INTRODUCTION

The use of cosmetics for routine body care dates back to ancient times. In recent years, the global demand for cosmetic products has surged, driven by growing awareness of personal grooming [1] and the influence of widespread advertising in mass media [2]. The beauty industry has consistently expanded, with an average annual growth rate of approximately 5%. Notably, the cosmetics and personal care sector has demonstrated remarkable resilience, maintaining steady growth even during economic fluctuations [3].
Cosmetics refer to products designed for application to the human body or specific body parts, whether by pouring, rubbing, sprinkling, spraying, or direct application. Their primary purpose is to enhance appearance, promote attractiveness, cleanse, or modify one's look [4]. The term "cosmetics" originates from the Greek word "kosmeticos," meaning "to adorn." [5]. This broad category includes items such as mascara, toothpaste, shampoos, conditioners, aftershave lotions, creams, and skincare products. Additionally, cosmetics encompass face powders, perfumes, lipsticks, nail polish, eye and facial makeup,

hair dyes, hair sprays, deodorants, and antiperspirants [6]. However, prolonged use of cosmetics can lead to various adverse effects on the body due to the presence of toxic metals. Researchers have confirmed that cosmetic products contain heavy metals such as lead, cadmium, chromium, arsenic, mercury, and nickel, which can exist as either ingredients or impurities in these products [7]. A recent study conducted by Alqadami et al. reported that 34 analysed body whitening creams contained varying concentrations of heavy metals, including cd, Pb, Hg, and As [8].

Cosmetics, preparations repeatedly applied directly to the human skin, mucous membranes, hair and nails, should be safe for health, however, recently there has been increasing concern about their safety. Unfortunately, using these products in some cases is related to the occurrence of unfavorable effects resulting from intentional or the accidental presence of chemical substances, including toxic metals. Heavy metals such as lead, mercury, cadmium, arsenic and nickel, as well as aluminum, classified as a light metal, are detected in various types of cosmetics (colour cosmetics, face and body care products, hair cosmetics, herbal cosmetics, etc.). In addition, necessary, but harmful when they occur in excessive amounts, elements such as copper, iron, chromium and cobalt are also present in cosmetic products. Metals occurring in cosmetics may undergo retention and act directly in the skin or be absorbed through the skin into the blood, accumulate in the body and exert toxic effects in various organs. Some cases of topical (mainly allergic contact dermatitis) and systemic effects owing to exposure to metals present in cosmetics have been reported. Literature data show that in commercially available cosmetics toxic metals may be present in amounts creating a danger to human health.

Cosmetic products contain numerous metals used as pigments, UV filters, preservatives, antiperspirants, and antimicrobial agents, as well as occurring as unintentional pollutants, and therefore represent a significant source of metal exposure. These include among others the metal allergens (e.g., nickel, chromium, and cobalt), as well as metals characterized by a high toxicity (e.g., cadmium, lead, mercury, and arsenic). Allergic skin reactions are the most commonly occurring reactions to metals present in cosmetics, with nickel the most important metal allergen. Cosmetics belong to the group of household products that most often cause allergic reactions, but until now insufficient attention has been paid to the allergenic potential of metals in these preparations. The possible presence of metals in cosmetics, including those capable of inducing allergic reactions, in conjunction with reports of allergy due to the presence of metals at low concentrations (below 1 μg/g), shows that the limits of metals recognized as “unavoidable impurities” should be defined and efforts undertaken to reduce the content of metals in cosmetics. Heavy metals are elements with a specific density greater than 5 g/cm³, known for their potential toxicity to living organisms and the environment [9]. Human exposure to heavy metals occurs through various sources, including soil, water, food, and cosmetics, as these metals are naturally present in the environment. While many countries have imposed restrictions or set permissible limits on the use of heavy metals in cosmetic formulations, these limits vary across regions, making it challenging to establish universal regulations. For instance, the

U.S. Food and Drug Administration (USFDA) and Health Canada have set acceptable lead (Pb) limits at 1.0 mg/kg and 10 mg/kg, respectively [10,11]. However, many developing countries

Still lack specific legislation to regulate the import, distribution, and use of cosmetic products containing heavy metals.

A study by Nancy et al. assessing metal contaminants in various cosmetic products found that these contaminants primarily originate from minerals used as solid fillers and pigments in formulations [12]. Heavy metals present in personal care products (PCPs) can gradually penetrate the body, accumulating in

soft tissues such as the liver, kidneys, brain, and lungs. Over time, this accumulation may lead to severe health issues, including anxiety, nerve damage, depression, memory loss, kidney cancer, skin cancer, lung cancer, and behavioral disorders [13].

The presence of toxic metals in cosmetics poses significant health risks due to their accumulation in the body, leading to dermatological and systemic issues. Despite regulatory limits, inconsistencies across regions and the use of unregulated products worsen the problem. Developing protective topical gels with metal-chelating and skin-barrier- enhancing properties can help minimize metal absorption. These formulations, incorporating natural and synthetic detoxifying agents, are essential for mitigating metal toxicity and ensuring consumer safety.

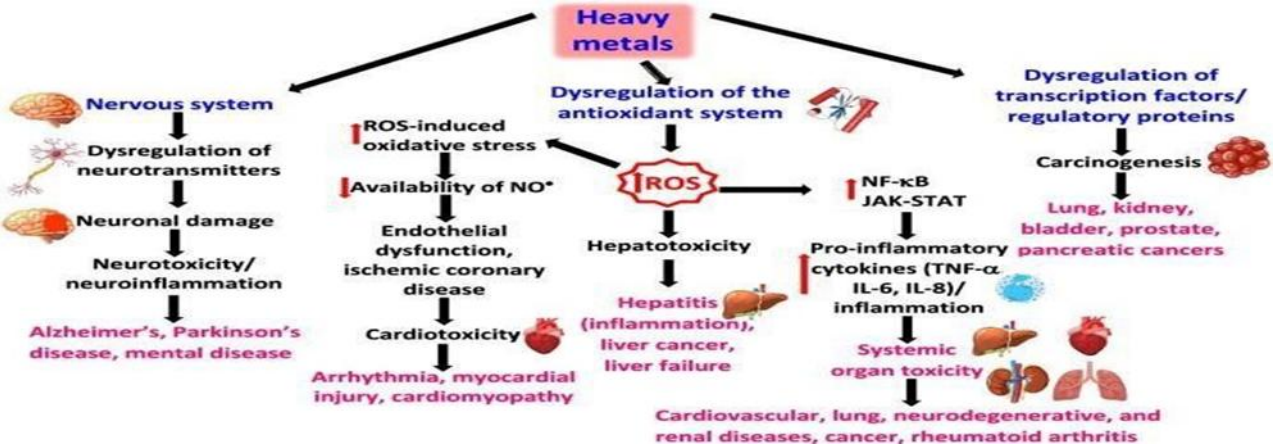


Figure no 1: Absorption mechanism of heavy metals into the body

Remarkable route for penetration of cosmetic ingredients is skin dermas which primarily protect sub-dermal and internal body organs. The application of cosmetics products on external skin reach the cell environment through hair follicles, sweat pores and finally blood capillaries for the function for which to be chosen. Although raptness through the skin is a slow process but continuously long-term use of cosmetics increases the concentration. However, inclusion of heavy metals to contaminant level accelerate the accumulation and also cause toxicity in the form of different disorders. The electrophilic substitution of heavy metals with essential elements in key biomolecules appear more threatening to human body. The following sections will explain the hazardous effects and mechanisms associated with the hazardous effects due to Hg, Pb, Cd and Cr; found in cosmetics.

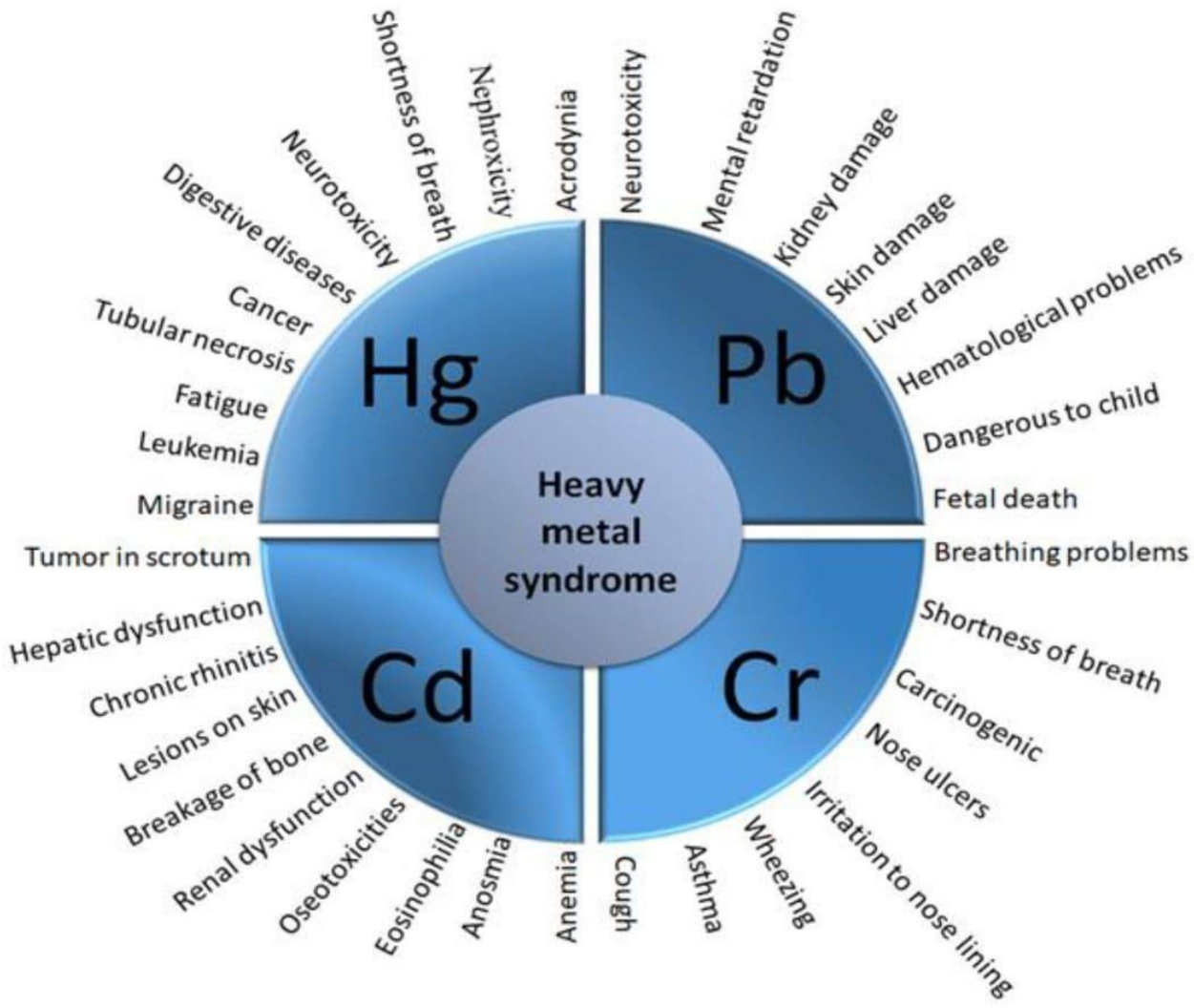


Figure No. 2 Side effects of heavy metal

2] LITERATURE REVIEW :

1] Ullah, H., Noreen [2013] :

The study was undertaken in order to determine heavy metal content in fifteen (n = 15) cosmetics products both imported and locally manufactured by unauthorized company marketed at district Kohat, Khyber Pakhtunkhwa, Pakistan. An analytical test was performed for eight metals in cosmetics products using flame atomic absorption spectrophotometer. The overall mean (n = 15) concentration for each heavy metal was analyzed i.e. Pb, Cd, Cu, Co, Fe, Cr, Ni, Zn were 141.6 ± 0.016, 0.238 ± 0.001, 26.62 ± 0.012, 0.527 ± 0.002, 860.8
± 0.061, 0.074 ± 0.002, 0.674 ± 0.002
and 268.6 ± 0.086
µg/g, respectively.

2] Draelos, Z.D., [2015] :

Dermatologists have become accustomed to thinking of cosmetics as substances that scent and adorn the

body, but do not alter structure and function. This is is in line with the current regulatory approach to cosmetics; however, cosmetics were actually the first drugs designed to treat the mind, body, and soul. The history of human cosmetic use dates back 6000 years and was embraced by almost every society to the far reaches of the earth in some form. If we consider body decoration a form of cosmetics, then cosmetic use began 100 000 years ago during the African Middle Stone Age. From this extensive history, it appears that the human desire to attend to the external body for appearance and ultimately disease purposes is innate.

3] Khan, A.D., Alam, M.N., [2019]:

The word 'cosmetics' is taken from a Greek word "kosmeticos" which means to adorn. Since early days materials used for beautification or improvement of appearance comes under the category of cosmetics. People want to look beautiful and the concept of cosmetics is as old as mankind and civilization. The urge to beautify one's own body and look beautiful has been an urge in the human race since the tribal days.

4] Alqadami A, Naushad M, Abdalla M, et al[2017] :

In this study, the determination of noxious heavy metals, cadmium (Cd), bismuth (Bi), mercury (Hg), titanium (Ti), lead (Pb) and metalloid arsenic (As) in skin-whitening cosmetics were examined using microwave digestion and inductively coupled plasma atomic emission spectrometry method. A complete digestion of cosmetics samples was achieved using a mixture of hydrofluoric acid/hydrogen peroxide/nitric acid. The quantification of the target compounds was done by standard addition method. The excellent quality parameters for instance, detection limits, As (4.6 ppb), Bi (7.9 ppb), Cd (0.45 ppb), Hg (3.3 ppb), Pb (3.8 ppb), Ti (4.3 ppb), linearity ($r2 > 0.999$) and run-to-run and day-to-day precisions with relative standard deviations <3% were obtained. The recovery rates for standard reference materials were found between 90 and 105%. The average concentration of heavy metals in cosmetics samples were in the range of 1.0-12.3 (µg g-1, As), 33-7097 (µg g-1, Bi), 0.20-
0.6 (µg g-1, Cd), 0.70-2700 (µg g-1, Hg), 1.20-143 (µg g-1, Pb) and 2.0-1650 (µg g-1, Ti).

5] Appenroth KJ [2010] :

A heavy metal is defined as such mainly on the basis of its specific weight, but the application of the term "heavy metal" to an element often leads to an expectation that it is toxic. Therefore, it does not seem sensible not to use the term any longer.
However, in plant science, this term is so widely used that it would be very difficult to eliminate it. Instead, we suggest that it would be better to define an element as a "heavy metal" on the basis of the periodic table of the elements.

6] Gondal, M.A., Seddigi, Z.S., Nasr, M.M., Gondal, B., [2010] :

Laser Induced Breakdown Spectroscopy (LIBS) technique was applied to determine the concentrations of different toxic elements like lead, chromium, cadmium and zinc in four different lipstick brands sold at local markets in Saudi Arabia. These samples contain toxic elements like lead, cadmium and chromium which are carcinogen dermatitis, allergic and eczematous. Their extraction from human body takes over 40 years and accumulation in the body cause problems like disruption of nervous systems and kidney damage. They could trigger to systemic lupus erythematosus (SLE). In order to test the validity of our LIBS results, standard technique like (ICP- AES) was also applied

7] US FDA Federal Food, Drug & cosmetic Act on hazardous chemicals in cosmetics. title 21. chapter 9: Food and Drugs. Subchapter vi: cosmetics. 2018
The laws of the United States are organized by subject into the United States Code. The United States Code contains only the currently enacted statutory language. The official United States Code is maintained by the Office of the Law Revision Counsel in the United States House of Representatives. The Office of the Law Revision Counsel reviews enacted laws and determines where the statutory language should be codified related to its topic. The Federal Food, Drug, and Cosmetic Act and subsequent amending statutes are codified into Title 21 Chapter 9 of the United States Code.

8] G Kumar, M Bhatt, PP Badoni - Indian J Pharm Educ Res, 2022 archives.ijper.org Skin aging is one of the main issues related with skin as each part of body ages with the time, So, to avoid this problem a novel formulation was designed in which citric acid as exfoliating agent will entrapped in thermodynamically stable, lecithin-based pluronic organogels. Objectives: The basic purpose of the study is to formulate a non-irritating and biocompatible citric acid loaded lecithin pluronic organogel for the treatment of skin aging. Materials and Methods : All the eight formulations (F1-F8) of lecithin pluronic organogel of citric acid was prepared by fluid filled fiber mechanism with different composition of pluronic f127.The FTIR study was revealed that no interaction observed between the drug and excipients.

9] Kapupara, P.P., Dholakia, S.P., Patel, V.P., Suhagia, B.N., 2011. Journal of chemical and pharmaceutical research preparations. J. Chem. Pharm. Res. 3, 287–294.
Millions of individuals worldwide regularly use cosmetics, personal care items, and tattoos. Tattoo ink and other makeup cosmetics also contain potentially toxic heavy metals. Heavy metals may build in the body after prolonged exposure. Most of them, including Pb, Cd, Hg, As, and Sb, are carcinogenic, allergenic, neurotoxic, teratogenic, and mutagenic contributing to hair loss and other cosmetic issues.Despite of numerous researches around the world and regulations on cosmetic items in developed countries to determine safe levels of heavy metals, most consumers have not knowledge enough about the related risks, especially in developing nations where equivalent regulations are absent. In addition,
everyday discarded cosmetics by customers pollute the environment, pose threats to microbes, plants, and animals, and are found in the solid waste and wastewater created by the cosmetic business. For these reasons, research, analytical analysis, publishing, surveying, reviewing and enhancing consumers' understanding of current laws, regulations, legislation, and recommendations of the U.S. Food and Drug Administration (US FDA), World Health Organization (WHO), U.S. Environmental Protection Agency (US EPA), and others are all necessary to raise public awareness about the hazards posed by heavy metals. The current mini-review aims to summarize cosmetics and tattoos' historical background and development, focusing on their hazardous ingredients, health impact, and allowable levels of heavy elements according to regulations.

10] Salwa M. Raweh, Maged Alwan Noman, Mahmoud Mahyoob Alburyhi, Abdalwali Ahmed Saif. Formulation And Evaluation of Anti-Acne Gel of Azadirachta Indica Extract Herbal Product. European Journal of Pharmaceutical and Medical Research. 2024, 11(2), 427-433.
The objective of this study was to produce a Carbopol 940 based gel formula containing an Azadirachta indica leaf extract and evaluate its anti-acne potential. The ethanolic extract was derived from the dried

leaves of Azadirachta indica and was subjected to a phytochemical evaluation. Three gel formulations of Carbopol 940 containing an Azadirachta indica extract in three different concentrations, i.e., 1, 2, and 3% w/w were prepared. These gels were evaluated for their physical appearance, antimicrobial activity, skin irritability, pH, spreadability, and viscosity. The prepared formulas were stable, greenish and homogeneous. None of them showed irritation to the skin. The spreadability (g.cm/sec), viscosity (cps), and pH of all three formulations was 34.68, 53 270–65 400, and 7–8, respectively. Gel-III exhibited the highest antimicrobial potential against Propionibacterium acne, the main causative organism of acne with a zone of inhibition of 16.2 ±
0.6 mm. It was revealed from the acne healing studies that the elimination time for the acne treated with Gel-III was 15 days. A formulation gel containing 3% w/w extract showed better antimicrobial activity, physicochemical characteristics, and pharmacological parameters than the other formulations. It can be concluded that the acne healing process was faster with the gel formulation containing 3% w/w of the Azadirachta indica extract, proposing that this formulation is a promising candidate for acne healing.

11] Bhakti Todmal. A Research on Formulation and Evaluation of Diclofenac Sodium Gel by Using Carbopol 940. World Journal of Pharmaceutical Research. 2024; 13, Issue 10, 578-592.

It is phynyl acitic acid derivative developed as anti-inflammatory agent. It has analgesic anti- inflammatory antipyretic like actions like other NSAIDS. . It is recommended in long term treatment of rheumatoid arthritis, osteoarthritis and ankylosing spondylitis. It is also useful acute mescuskelatal disorder post-operative pain and dysmenorrhea Diclofenac sodium gel were developed in seven different formulations (F1 to F7) by employing different grades of polymers such as Hpmck4m and Crbopol940. There the various Diclofenac gels are available in market.but the propose gel is formulated with two key ingredients oleoresin, and l linseed oil contribute to anti- inflammatory effect. The formulations were evaluated for various physical parameters, ph spredibility , drug relese excrutability studies drug released mechanisms.B7formulation showed maximum drug release of 8 hours and maximum drug. Finally the gel formulations found to be economical and may overcome the draw backs associated with the drug during its absorption.

12] Nesterenko P, Jones P. Single-column method of chelation ion chromatography or the analysis of trace metals in complex samples. Jchromatogr A. 1997;770:129–135.

A single-column chelation ion chromatographic system for the preconcentration and separation of trace transition metals is described. The system includes standard chromatographic equipment with a post-column reagent system based on the reaction with 4-(2-pyridylazo) resorcinol followed by photometric detection at 495 nm. Iminodiacetic acid bonded to 5 μm silica (Diasorb IDA) was used as a chelating stationary phase. The strong complexing ability in combination with good kinetics of complexation and ion-exchange selectivity of iminodiacetic functional groups allow both preconcentration of Mn, Co, Cd, Zn, Ni and Cu from waters of high salinity and efficient separation with the same column. The retention characteristics of alkaline-earth and transition metal ions on Diasorb IDA silica (250×4 mm I.D.) column was investigated for a variety of eluents including nitric acid, maleic, malonic, citric, dipicolinic, picolinic, tartaric and oxalic acids. The influence of ionic strength on retention of metal ions involving high nitrate and chloride concentrations was also evaluated. The baseline separation of preconcentrated metals was achieved using a three-step gradient elution scheme which involved first, flushing of the column loaded

with the sample with 0.5 M KCl−0.5mMHNO3 for 10 min, followed by 80 mM tartaric acid for 20 min and finally 10 mM picolinic acid for 20 min.

3] AIM AND OBJECTIVE:

AIM: Development and Evaluation of A Protective Topical Gel Against Metal Toxicity From Cosmetic Products.

➢ OBJECTIVE:

1. Developed formulation should be simple and economically affordable.
2. To minimize the metal toxicity produced by cosmetic
3. Developed formulation should be effective and safe.
4. To safeguard the skin irritation, information and damage by exposure from skin, reducing the risk of prolonged exposure.
5. To reduce the absorption of toxic metals into the skin

4] PLAN OF WORK:

1. Literature Survey.
2. Procurement of Drug excipients
3. Determination of Physiochemical Properties of All Drug.
4. Formulation Development.
5. Selection of Ingredients.
6. Preparation of Gel.
7. Evaluation Of Gel:

- ➢ pH
- ➢ Spreadability (gm.cm/s)

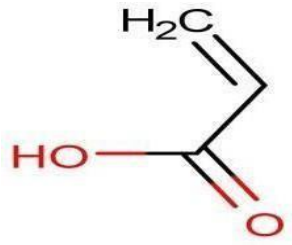
- ➢ Viscosity (cps)
- ➢ Homogeneity

6] DRUG AND EXCIPIENT PROFILE :

6.1 Carbapol 940:

Chemical Nature: Carbopol 940 is a synthetic high molecular weight polymer of acrylic acid, cross-linked with polyalkenyl ethers or divinyl glycol.

Chemical structure :



Appearance: White, fluffy, hygroscopic powder.

Solubility: Dispersible in water, ethanol, and glycerin.

pH Sensitivity- Requires neutralization (usually with triethanolamine or sodium hydroxide) to form a gel and reach maximum viscosity.
Viscosity Range- High viscosity (40,000 – 60,000 cps at 0.5% concentration).
Thickening Efficiency- Provides excellent thickening at low concentrations (typically 0.1%–1%).
Rheological Properties- Forms clear, stable, and smooth gels with shear-thinning behavior.

Stability- Stable over a wide pH range (5.0–10.0), but loses viscosity in acidic pH (<4.0).
Compatibility- Compatible with a wide range of cosmetic and pharmaceutical actives, but incompatible with high levels of electrolytes.

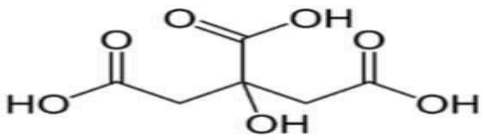
Non-toxic & Non-irritant- Widely used in topical and mucosal formulations due to good biocompatibility.
Shear Sensitivity: Excessive mixing can break down the gel structure.

- **Uses of Carbopol 940 in Gel Formulation:**

1] **Gelling Agent**- Used to form transparent or translucent gels in both hydrophilic and hydroalcoholic systems.
2] **Viscosity Enhancer**- Improves the consistency and texture of gels, making them easy to apply and spread.
3] **Suspending Agent-** Helps suspend insoluble ingredients like powders or APIs in semi- solid formulations.
4] **Bioadhesive Agent-** Provides mucoadhesion in nasal, buccal, and vaginal gels to increase residence time.

6.2 Citric Acid :
Chemical Name: 2-hydroxy-1,2,3-propane-tricarboxylic acid
Molecular Formula: $C_6H_8O_7$

Molecular structure :



Nature: Weak organic acid

Appearance: White crystalline powder **Solubility**: Highly soluble in water and alcohol **pH:** Acidic (typically 2–3 when in solution)
Origin: Naturally found in citrus fruits; commercially produced by fermentation (e.g., using Aspergillus niger)

Uses of Citric Acid in Gel Formulations

6.2.1 **pH Adjustment-** Used to maintain or adjust the pH of the gel to ensure product stability and compatibility with skin or mucosa.

6.2.2 **Preservative Enhancement (Synergistic Effect)**- Enhances the effectiveness of preservatives like parabens and sorbates by lowering pH and creating an unfavorable environment for microbial growth.

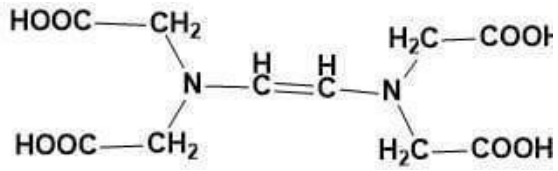
6.2.3 **Buffering Agent-** Works in combination with sodium citrate to maintain a stable pH over time.

6.2.4 **Chelating Agent-** Binds metal ions (e.g., iron, copper) which could otherwise catalyze degradation of the gel or reduce preservative efficacy.

6.3 EDTA :

Full Form: Ethylenediaminetetraacetic acid.

Chemical structure :



Chemical Nature: A polyamino carboxylic acid; acts as a chelating agent.
Chelating Function: Binds to metal ions like Ca^{2+}, Mg^{2+}, Fe^{3+} to form stable, water- soluble complexes.
Common Forms Used: Disodium EDTA (Na_2EDTA) Tetrasodium EDTA
Appearance: White, crystalline powder.

Solubility: Soluble in water (varies with form – disodium salt more soluble than pure acid).
pH Range: Effective in pH range of 3 to 10.

Uses of EDTA in Gel Formulation (Pharmaceutical & Cosmetic):

6.3.1 **Chelating Agent-** Prevents metal ion-catalyzed degradation of active ingredients and excipients. Enhances product stability and shelf-life.

6.3.2 **Preservative Enhancer-**Enhances the effectiveness of antimicrobial preservatives (e.g., parabens, phenoxyethanol). Disrupts microbial cell wall integrity by removing metal ions needed for survival.

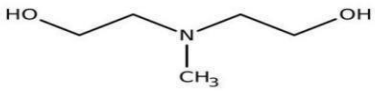
6.3.3 **Stabilizer-** Prevents oxidative degradation by binding trace metals like iron and copper that catalyze oxidation. Particularly useful in formulations containing vitamins or essential oils.

6.4 Triethanolamine (TEA) :

Chemical Nature- Organic compound with both amine and alcohol functional groups.

Chemical formula: $C_6H_{15}NO_3$.

Chemical structure :



Appearance- Clear, colorless to pale yellow, viscous liquid with a slight ammonia-like odor.

Solubility- Soluble in water, alcohol, and other polar solvents.

pH Adjuster- Acts as a weak alkaline agent to adjust and stabilize the pH of formulations.

Emulsifier & Surfactant- Has surface-active properties; helps in emulsion stabilization and gel consistency.

Buffering Agent- Maintains the pH within the desired range, especially in formulations with carbomers.

Uses of Triethanolamine in Gel Formulations:

1] Neutralizing Agent for Carbomers- Used to neutralize carbomer polymers (e.g., Carbopol) to form clear, stable gels. Converts the carbomer dispersion into a viscous gel by increasing pH.

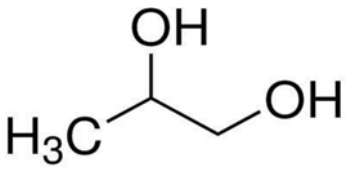
2] pH Adjustment- Maintains the pH of gel between 5.5–7.5, optimal for skin application and gel stability.

3] Emulsion Stabilizer- Helps in forming and stabilizing oil-in-water emulsions in gel-cream products.

4] Thickening Agent- In combination with gelling agents, enhances viscosity and spreadability.

6.5 Propylene Glycol :

Chemical Name: 1,2-propanediol **Molecular Formula:** $C_3H_8O_2$ **Molecular structure :**



Appearance: Clear, colorless, odorless, and slightly viscous liquid **Solubility**: Miscible with water, alcohols, and many organic solvents **Polarity:** Highly polar solvent
Viscosity: Moderate viscosity, helps in adjusting rheological properties

Hygroscopic Nature: Absorbs moisture from the air

Boiling Point: Around 188°C

Toxicity: Low toxicity; considered safe for pharmaceutical and cosmetic use

Stability: Chemically stable under normal storage condition.

Uses of Propylene Glycol in Gel Formulation (Points):

6.5.1 **Solvent-** Used to dissolve active pharmaceutical ingredients (APIs) that are poorly soluble in water. Ensures uniform distribution of actives in the gel.
6.5.2 **Humectant-** Retains moisture in the gel. Prevents drying and cracking of the gel during storage or application.
6.5.3 **Penetration Enhancer-** Enhances transdermal and dermal delivery of drugs. Improves absorption of the drug through the skin

5] MATERIAL AND METHOD :

❖ **Carbopol 940:**

Carbopol is an acrylic polymer. Carbopol is non-toxic and non-irritating so that it is suitable for gel preparations. Carbopol 940 is often used as a gelling agent in gel preparations. Concentration of carbopol 940 as a gelling agent needs to be concerned to obtain a good gel preparation. The selection of carbopol 940 is due to its large viscosity range of 40,000- 60,000 cP. The concentration of carbopol 940 gelling agent directly affects the viscosity of the preparation which also affects the physical properties of the gel preparation[14].

❖ **EDTA (Ethylenediaminetetraacetic acid):**

EDTA is commonly used in pharmaceutical and cosmetic gel formulations. It serves primarily as a chelating agent, which means it binds metal ions (such as Arsenic, Lead,CD,Hg, calcium, magnesium, iron, and others**).** EDTA helps to bind and remove heavy metal ions that may be present in cosmetics products [15].

❖ **Citric Acid :**

The basic purpose of use of citric acid is to formulate a non-irritating and biocompatible cosmetic products . Citric acid is reported to function in cosmetics as a chelating agent, pH adjuster, or fragrance ingredient. Citric acid increases the shelf life of cosmetic and skin care products by acting as a preservative. Citric acid helps maintain the optimal pH of products, which ensures skin compatibility. Citric acid can help reduce the appearance of scars, spots, and other pigmentation issues, Citric acid can contribute to toning and firming the skin[16]

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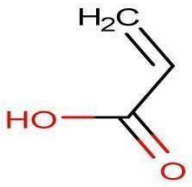
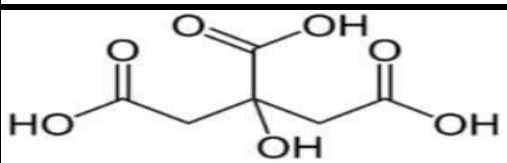
❖ **Triethanolamine [TEA]:**

Use Cosmetic Triethanolamine is reported to function in cosmetics as a surfactant or pH adjuster, and it can be used in fragrances. Most of the other triethanolamine ingredients are reported to function in cosmetics as surfactants, skin conditioning agents, or hair conditioning agents. TEA- sorbate is reported to function only as a preservative. primarily acts as a pH adjuster and emulsifier, ensuring a stable and balanced gel consistency, while also helping to solubilize ingredients and improve texture[17] .

❖ **Propylene Glycol :**

It is a colorless, odorless, and tasteless liquid that is hygroscopic (absorbs water)

In gel formulations, propylene glycol plays multiple roles — acting as a humectant to retain moisture, a solvent to enhance the effectiveness of active ingredients, and a stabilizer to improve texture and shelf life. Although propylene glycol must be heated or briskly shaken to produce a vapor[18].

SR NO	NAME OF CHEMICALS	CHEMICAL STRUCTURE	USES IN GEL FORMULATION
1]	Carbapol 940	 poly(1-carboxyethylene)	● Gelling agent
2]	Citric Acid	 2-hydroxypropane-1,2,3-tricarboxylicacid	● PH adjuster, ● Preservative

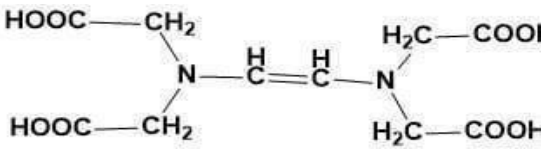
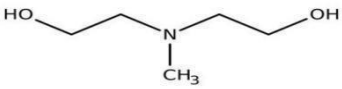
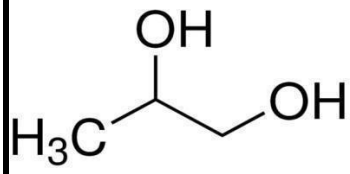
3]	EDTA	 2,2'-((2-(bis(carboxymethyl)amino)ethyl)azaned-iyl)diacetate	● Chelating agent
4]	Triethanolamine	 2,2',2"-nitrilotriethanol	● Surfactants ● Emulsifier ● Viscosit y Modifier
5]	Propylene Glycol	 propane-1,2-diol	● Humectant ● Improve texture ● Preservative

Table No : 1 Formulation Ingredients Of Gel

➢ **Method Of Gel Formulations:**

Carbopol 940 gel formation involves a two-stage process:

1] **first,** dispersing and hydrating the polymer in a solvent, followed by neutralizing the solution with a base like triethanolamine (TEA), which causes the Carbopol to swell and thicken into a gel. Here's a more detailed explanation:

2] **Dispersion and Hydration-** Carbopol 940 is a cross-linked acrylic acid polymer that is initially in a dry, powder form. To form a gel, it needs to be dispersed and hydrated in a suitable solvent, typically water. Slowly and carefully sprinkle the Carbopol powder into the solvent while stirring rapidly to avoid forming clumps. Continue stirring until a thin, cloudy solution without lumps is achieved.

3] **Neutralization-** The Carbopol polymer has negatively charged carboxylic groups that are protonated in acidic conditions and unprotonated in alkaline conditions. To form a gel, the solution needs to be neutralized to a pH around 7, which causes the Carbopol particles to swell and form a gel-like structure. This is achieved by adding a base, such as triethanolamine (TEA) or sodium hydroxide, to the solution. As the pH increases, the Carbopol particles swell, and the solution thickens into a gel

❖ **General Procedure:**

Firstly All the containers need to be sterilized by hot air oven and disinfected by ethanol .

Carbopol 940 was gradually dissolved in demineralized water with continuous stirring for 1 hour to prevent agglomeration.

Separately, disodium EDTA, citric acid, and triethanolamine were dissolved in demineralized water and stirred for 10 minutes.

Propylene glycol and cinnamon oil were then mixed with demineralized water and stirred for 10 minutes.

The disodium EDTA and triethanolamine solution was added to the Carbopol solution, and the pH was adjusted to 7.4 by stirring for 10 minutes.

Finally, the propylene glycol and cinnamon oil solution was incorporated into the mixture, followed by stirring for 10 minutes until a clear and consistent gel base was obtained.

INGREDIENT	G1	G2	G3	G4	G5
CARBOPOL 940	5 gm	5.2 gm	4.8 gm	5.5 gm	5.0 gm
EDTA	1gm	1.5 gm	1 gm	0.5 gm	1 gm
CITRIC ACID	0.5 gm	0.5 gm	0.5 gm	0.5 gm	0.5 gm
TRIETHANOLAMINE	1 ml	1 ml	1 ml	1 ml	1 ml
PROPYLENE GLYCOL	10.5 ml	10.3 ml	10.4 ml	10.1 ml	10.2 ml
CINNAMON OIL	Q.S	Q.S	Q.S	Q.S	Q.S
WATER	Q.S	Q.S	Q.S	Q.S	Q.S

Table No 2: Formulation Batches

Figure No: 3 Formulation Batches

7] EXPERIMENTAL WORK:

1] Physical Appearance- Physical parameters, including colour and appearance, were evaluated through visual inspection.

Figure No: 4 Physical Appearance

2] pH- A 1.0 g sample of the gel was precisely weighed and dispersed in 100 mL of purified water. The pH of the resulting dispersion was measured using a digital pH meter, which was calibrated prior to use with standard buffer solutions at pH 4.0, 7.0, and 9.0. Measurements were conducted in triplicate, and the average values were calculated[19].

Figure no.5 : pH Determination

3] Viscosity- The viscosity of the gel formulations was determined using a Brook-field DV- E viscometer (RVDVE). Spindle No. 07 was inserted into each formulation, and measurements were conducted at 24 ± 1°C. The gel formulations were prepared using distilled water[20].

Figure No 6 : Brookfield viscometer

4] Spreadability:

A standard glass slide was used, onto which 0.5 g of gel was applied in a 1 cm diameter circle. Another glass slide was placed on top, and a 125 g weight was applied for 5 minutes to evenly spread the gel into a thin layer. After removing the weight and any excess gel, the slides were positioned with the upper slide secured by a 20 g weight. The time taken for the slides to separate was recorded.

The spreadability was recorded using the following formula.[21].

(S = M / T)

Where,

S – Spreadability in grams/seconds; M – Mass in grams;

T – Time in seconds.

Figure no.7: Spreadability Parameter

5] Homogeneity:

All formulated gels were visually examined for homogeneity after being set in their containers. Their appearance and the presence of any accumulations were assessed. The results are presented in the table below[22].

6] Stability studies:

Accelerated stability studies were conducted on the optimized formulation at 40 ± 2°C and 75 ± 5% relative humidity over a period of 3 months. The gel was stored in aluminum tubes, and its physicochemical properties, physical appearance,and viscosity were periodically evaluated using the same methods applied in the initial gel assessments[23].

8] RESULT AND DISCUSSION:

1] Physical appearance:

The prepared gel was physically evaluated and observed to be smooth, with a faint whitish color and no visible foreign particles.

2] pH:

The pH of the gel formulations was determined using a digital pH meter, with values ranging from **6.70 to 7.1.** The pH measurements for all formulations are summarized in **Table 2** and illustrated in **Figure 8.**

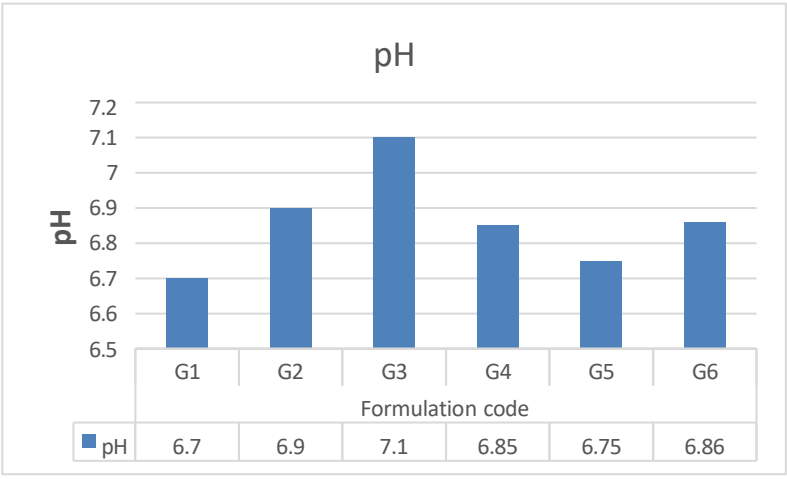


Figure No 8 : pH of Formulations

3] Viscosity:

The viscosity of all formulations ranged from **18230 to 22230 cps**, as presented in **Table 2**

and illustrated in **Figure 9 .**

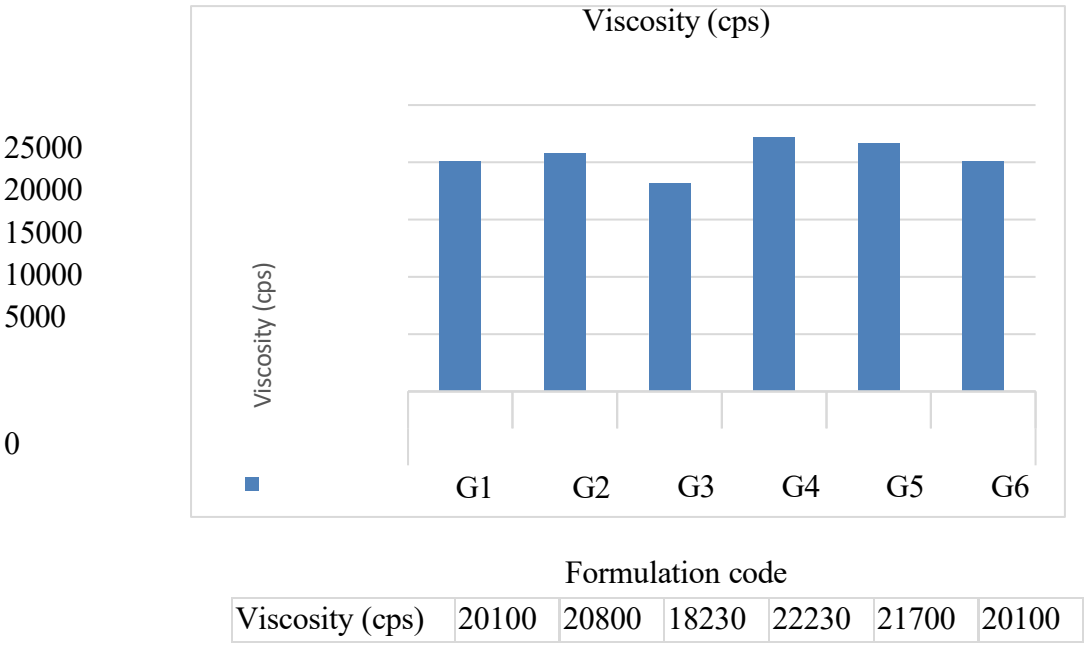


Figure no 9 : viscosity determination

4] Spreadability:

The spreadability of all prepared gel formulations was assessed, with values ranging from **15.91 to 22.5 g cm/s.** The spreadability results for all formulations are detailed in **Table 2** and depicted in **Figure 10.**

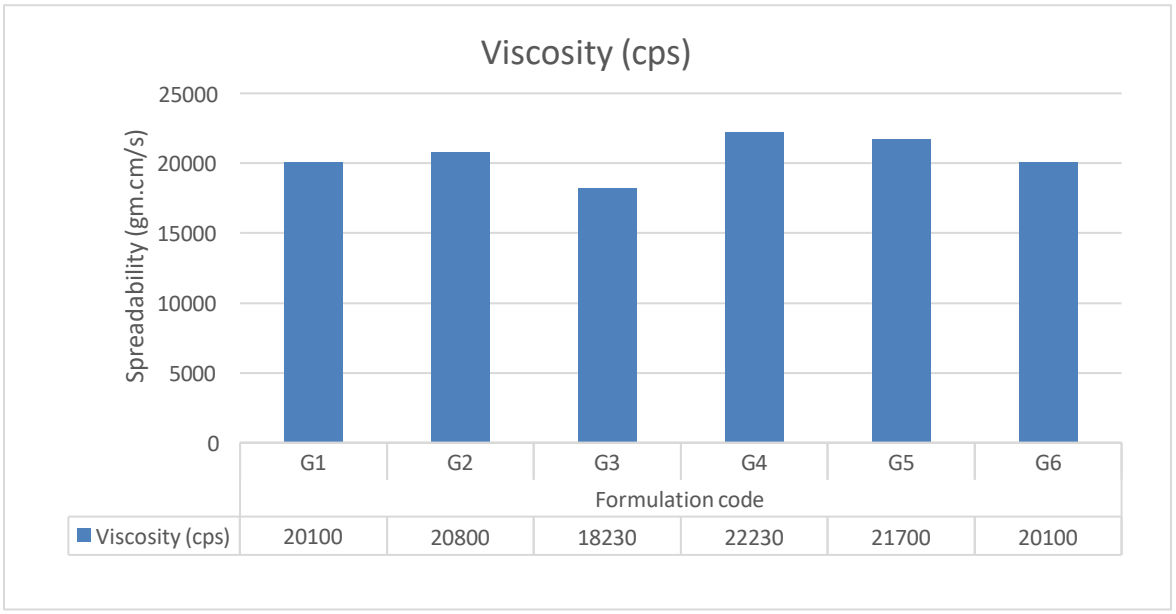


Figure No 10 : Spreadability of all formulations

5] Homogeneity:

All gel formulation batches exhibited good homogeneity, free from lumps. The majority of the formulations displayed excellent uniformity with no signs of grittiness.

6] Stability studies:

The gel was examined for physicochemical screening after the optimised formulation G2 was stored for three months at 40 ± 2°C and 75 ± 5% relative humidity. There was no discernible crystallisation and the gel had a smooth, slightly faint whitish color. The G3 formulation was found to have a pH of 6.88 and a viscosity of 20800 cps. As a result, the gel's phytochemical properties were all comparable to those at the beginning (0 months), demonstrating its stability.

Parameter	**Formulation code**					
	G1	**G2**	**G3**	**G4**	**G5**	**G6**
pH	6.70	6.90	7.1	6.85	6.75	6.86
Spreadability (gm.cm/s)	15.91	22.5	14.26	20.88	21.22	22.1
Viscosity (cps)	20100	20800	18230	22230	21700	20100
Homogeneity	Good	Excellent	Good	Good	Good	Good

Table No 3: Evaluation parameters of gel formulation

7] complex Formation:

Di sodium EDTA + pb Acetate → Pb EDTA + Di sodium Acetae

Disodium EDTA

Cosmetics Review Board has found that disodium EDTA is safe. It is not a skin sensitizer nor a carcinogen, and does not penetrate through skin.

Pb Acetate

In several form of cosmetic Pb is present in form of Pb Acetate

Pb EDTA

Reddish brown precipitate is obtained after

Di Sodium Acetate

Water content present in carbapol gel causes hydrolysis into 2 molecules of NaOH and 1 molecule of Acetic Acid .

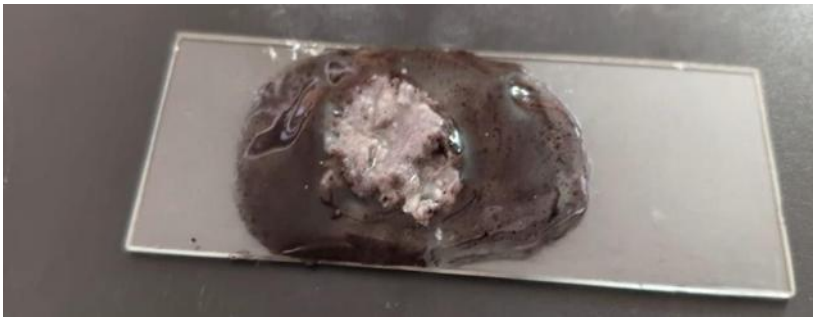


Figure No 11: Complex Formation Between Metal ion and EDTA

9] SUMMARY AND CONCLUSION:

The development and evaluation of a protective topical gel against metal toxicity from cosmetic products demonstrated promising physicochemical properties, stability, and effectiveness. The gel exhibited smooth texture, good homogeneity, and a faint whitish color with no visible foreign particles. The pH values (6.70–7.1) ensured skin compatibility, while the viscosity (18,230–22,230 cps) provided an optimal gel consistency. Additionally, spreadability (15.91–22.5 g·cm/s) was within an acceptable range, ensuring ease of application.

The optimized formulation (G2) showed excellent stability after three months of accelerated storage (40 ± 2°C and 75 ± 5% RH), with no crystallization or degradation. Its pH (6.88) and viscosity (20,800 cps) remained consistent with initial values, confirming its long- term stability. The optimized formulation enhances metal chelation (Disodium EDTA), hydration and penetration (Propylene Glycol), pH stability (Triethanolamine). These properties make the gel a promising protective barrier against heavy metal exposure from cosmetics, ensuring skin safety and long-term effectiveness.

10] Future Scope :

1. Advanced Formulation Development- Incorporation of Nanotechnology: Future formulations could explore the use of nanoparticles (e.g., zinc oxide, titanium dioxide, or liposomes) for enhanced skin penetration, sustained release, and improved protective
efficacy. Smart Polymers and Hydrogels: Intelligent delivery systems that respond to environmental triggers (e.g., pH, temperature, or metal ion concentration) can be integrated for targeted protection.
Multi-functional Gels: Combining metal chelation with additional cosmetic benefits such as anti- aging, moisturizing, or UV protection can increase consumer appeal and efficacy.

2. Broader Toxicological Evaluation- Long-term Safety Studies: Chronic dermal exposure studies using animal models or human volunteers to ensure safety with prolonged use. Dermatological Compatibility: Evaluation on different skin types (e.g., oily, dry, sensitive) and assessment for allergic or irritant reactions. Interaction with Cosmetic Ingredients: Further studies on the compatibility of the gel with common cosmetic ingredients to ensure stability and safety when co-applied.

3. Targeting Specific Metal Pollutants- Broader Metal Spectrum: Future versions of the gel can be formulated to protect against a wider range of toxic metals (e.g., arsenic, barium, manganese) in addition to lead, mercury, and cadmium. Geographic and Occupational Applications: Tailoring the formulation based on regional pollution profiles or specific occupational exposures (e.g., industrial workers, miners, beauticians).

4. Clinical and Regulatory Pathways-

Clinical Trials: Conducting Phase I/II human trials to evaluate efficacy, bioavailability, and user compliance under real-world conditions.

Regulatory Approvals: Filing for approval with regulatory bodies such as the FDA (as a cosmetic or over-the-counter drug), EU Cosmetic Regulation, or CDSCO in India.

5. Market Translation and Commercialization-

Product Line Expansion: The base formulation can be adapted into multiple product formats— creams, sprays, serums, masks—for various cosmetic applications.

Brand Collaborations: Opportunities to partner with skincare and cosmetic brands for co-branded products targeting pollution-conscious consumers.

Consumer Awareness Campaigns: Educating the public about metal toxicity and Promoting preventive skincare practices through dermatologists and cosmetic professionals.

6. Environmental and Social Impact- Sustainable and Green Chemistry: Future development can focus on using eco-friendly, biodegradable ingredients to reduce environmental load.

Public Health Initiatives: The gel can be part of public health programs in highly polluted regions, especially among vulnerable groups like children and women.

Cosmeceutical Innovation: With increasing consumer demand for health-oriented cosmetics, this research contributes to the growing field of cosmeceuticals that blend dermatological science with beauty.

7. To minimize the metal toxicity produced by cosmetic

8. To safeguard the skin irritation, information and damage by exposure from skin, reducing the risk of prolonged exposure.

9. To reduce the absorption of toxic metals into the skin.

10. The development of a protective topical gel against metal toxicity holds significant promise in the cosmetic and personal care industry, especially in an era where environmental pollution and heavy metal exposure are growing concerns.

11. Incorporating novel delivery systems such as liposomes, niosomes, or nanogels may enhance the bioavailability and sustained release of protective agents in the gel.

12. These systems can also improve skin penetration and provide a longer duration of protection.

13. This protective gel can be integrated into existing cosmetic routines, potentially as a primer or base layer under makeup or sunscreen.

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