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MINI-REVIEW

Overcoming Skin Damage from Pollution *via* Novel Skincare Strategies

Alexandros Charitakis[1], Sulaf Assi[1], Sakib Yousaf[1] and Iftikhar Khan[1,*]

[1]*School of Pharmacy and Biomolecular Sciences, Liverpool John Moores University, Liverpool L3 3AF, United Kingdom*

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Abstract: Urban pollution is one of the main problems encountered worldwide, with a major impact on public health as well as the environment. The health impact of urban pollution is not limited to respiratory conditions but also encompasses major skin problems, including irritation, skin ageing, and skin cancer. Toxic gases and particulate matter are the main pollutants that exhibit extensive local variability. The aforementioned pollutants are small particles that attach to the skin or penetrate it, enhancing free radicals' production inside the inner skin layers. This urges the need to propose cosmetic products that help prevent and/or minimise pollutants' effects on the skin, whether irritation, ageing, and cancer. Furthermore, intrinsic and extrinsic factors contribute to skin irritation and ageing. Intrinsic factors are within skin factors and include genetic and physiological characteristics of individuals. Moreover, extrinsic factors comprise environmental factors such as humidity, temperature, and smoke. Subsequently, active ingredients with anti pollutant properties addressed the intrinsic and extrinsic factors by four mechanisms: free radical neutralisation, film-forming ability, skin barrier enhancement, and fortification. Such ingredients include vitamin A derivatives, vitamin C derivatives, carbohydrates, and plant-based products. Yet, very limited studies have evaluated the effectiveness of the aforementioned active ingredients against irritation or ageing, which should be considered in future work.

Keywords: Skincare, pollutant, skin damage, skin barrier, penetration, particulate matter.

1. INTRODUCTION

Skin is the largest organ of the body that has direct contact with the environment and thus is in contact with air. Air pollution comprises harmful substances in the atmosphere that adversely affect human health. Such harmful substances include sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), particulate matter (PM), and airborne particles such as dust, tobacco, volatile pesticides, and various heavy metals such as lead [1]. In recent years, studies have shown that air pollution is an important factor in human morbidity and mortality, mainly caused by transportation exhaust, industry, and domestic kitchen cooking fires [2, 3].

The epidermis (the outer layer of skin) is composed of two different cell types, keratinocytes and dendritic cells. Moreover, many other cells like Largenhals cells or melanocytes and Merkel cells can also be found in lower quantities inside the epidermis. The epidermis makes the skin resistant to the passage of various substances. Corrosive and fat-dissolving substances destroy the epidermis by entering the body, causing oxygenation of the skin and resulting in premature ageing. Furthermore, skin atrophies *via* hydration, where the layers of the skin become thinner and hence greatly reduce skin elasticity. In addition, the activities of capillaries are reduced, and thus, the skin becomes dry and rough [4]. Usually, substances are transported from the skin pores or are removed *via* sebum secretion. However, when pollutants stick or clog onto those pores, they do not let the skin do this function effectively [5]; so the sebum crystallises, the pores become clogged, they expand and deform; hence free radicals are created, resulting in aesthetic problems on the skin including; wrinkles, sagging, discoloration and sometimes skin diseases. Numerous studies used pollutants (*e.g.*, dust, microparticles, and substances from cigarette smoke, *etc.*) to investigate the effectiveness of various active ingredients in detoxifying cells, fighting oxidative stress, and chronic inflammation [6-8]. Moreover, the aforementioned studies explored the effects of the active ingredients on activating genes that protect cells from environmental attacks and help them repair their damage. In this respect, many plants have been analysed for the presence of new active molecules and ingredients that could be used to design and develop cosmetic formulations for skin protection, especially in urban regions [9, 10]. In response to the latter increase in pollution, the cosmetic industry released more products to tackle pollution [11].

Several products that currently focus exclusively on protection against environmental pollution are sold in the cosmetics market. The so-called anti-pollution products contain active ingredients that isolate the skin from external environmental factors, forming on its surface a protective film like a "second skin" [12]. Some of them are enriched with antioxidants and anti-inflammatory ingredients that help strengthen the natural defences of the skin cells and repair skin damage. Similarly, to tackle the growing situation, the demand for anti-pollution products is always growing and expanding [7]. New "multifunctional" products, from creams and cleansing lotions to sunscreens, not only shield against pollution but offer additional benefits, including antioxidant protection, detoxification, and anti-wrinkle action.

2. SKIN AGEING

The skin possesses a large surface area, and consequently, its ageing can be caused by a variety of factors like medical, psychological, and social, all of which play pivotal roles in peoples' everyday lives [13, 14]. Skin damage/ageing is caused by intrinsic (*i.e.*, time-related) or extrinsic factors (*i.e.*, correlated with environment) [15]. Intrinsic skin deterioration is a phenomenon that is affected by genetic factors or even metabolism. For instance, it is an oxidative process that is associated with a progressive, age-

*Address correspondence to this author at the School of Pharmacy and Biomolecular Sciences, Liverpool John Moores University, Liverpool L3 3AF, United Kingdom; Tel: (+44) 151 231 2736; E-mails: I.Khan@ljmu.ac.uk; iftikharkhans@yahoo.com

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related decrease in antioxidant capacity combined with increased production of reactive oxygen species (ROS) by oxidative metabolism (*e.g*., lipid peroxidation) in the skin [16]. The clinical features of chronic skin ageing are mostly associated with the thinning of the epidermal and dermal layers, reducing elasticity levels, and increasing the presence/formation of fine wrinkles. Extrinsic skin ageing derives from the improvements in the process of structural and functional degradation of skin cells as a result of continuous exposure to harmful environmental factors like intense physical and psychological stress [17], cigarette smoke, air pollution, lack of sleep, temperature, bad nutrition habits, and exposure to ultraviolet (UV) radiation (Fig. **1**). A study conducted by Krutmann, *et al*. [18] concerning skin ageing has defined it as "external and internal factors and their interactions affecting human beings from conception to death, as well as the human body's response to these factors leading to biological and clinical signs of skin ageing."

Fig. (1). Extrinsic factors that promote skin ageing [18]. (*A higher resolution/colour version of this figure is available in the electronic copy of the article*).

3. AIR POLLUTION

3.1. Impact of Pollution

Pollution is a growing problem in many metropolitan regions around the world. Air pollutants are mainly anthropogenic and include CO, SO_2, (NO_x), volatile organic compounds, ozone, and PM (a mixture of solid and liquid particles of variable size and composition, which deliver a large number of pollutants) [19]. Exposure to these air pollutants is associated with harmful effects on the human skin, such as premature ageing, pigment spots, skin rashes, and eczema [20], which may worsen certain skin conditions, such as atopic dermatitis [21]. According to various studies, PMs mostly induce oxidative stress, skin ageing, and pigmentation [4]; ozone molecules may induce epidermal damage, reduce antioxidants, and generate ROS [22]. Moreover, the oxides mentioned above interact with the skin and cause oxidative damage, ROS generation, and lipid peroxidation, all of which interfere with cell metabolism [5, 23]. A cosmetic approach to this evolving problem involves the topical application of skincare products containing functional, active ingredients capable of counteracting pollution-induced skin damage [7].

Various sources of environmental pollution have been observed to cause skin damage. These have been identified as vehicular traffic and exhaust fumes, coal-burning power plants, industrial combustion, cigarette smoke, indoor domestic kitchen cooking fires, and volatile organic compounds. The two main groups of primary pollutants are considered to be PM [24], including polycyclic aromatic hydrocarbons (PAHs) and toxic gases such as CO_2, CO, SO_2, NO, NO_2, and other nitrogen oxides (NO_x) (Fig. **2**) [19, 25]. The major function of the skin is its ability to protect the inner parts of the human body, so the skin must be protected from all harmful/extrinsic factors. Pollution can potentially be dermatologically hazardous and have many severe effects, like inflammation, oxidative stress, and metabolic impairments, and could also engender cancer, which might be amplified by the deleterious synergy of the sun, particularly UVA [26].

Skin automatically protects itself from pollutants with the aid of every individual's immune system, but constant exposure to environmental pollutants may negatively impact the defence mechanisms [27]. There are pollutants like PAHs that have very effective penetrating abilities and can pass through the outer skin layer and cause high levels of damage without being induced to the inner layers of the stratum corneum [28]. For that reason, maintaining skin balance and protection is of great concern. This can be done by applying cosmetic formulations with film-former and structure enhancement abilities. These anti-pollution formulations contain mainly film-forming actives and antioxidants designed to enhance the integrity of the skin cells to act as a shielding barrier against pollutant particles (Fig. **2**). Active cosmetic ingredients can be employed not only to render direct contact of pollutants to the skin but also to eliminate the generation of ROS like free radicals. Thus, cosmetics formulations that achieve both of these characteristics are desirable. Moreover, the signal of proinflammatory stages (*i.e*., pathways like Keap1-Nfr2 and IKB-NFKB) can be prevented by using actives in cosmetic formulations to curb the short-term health damage caused by inflammation factors, such as cyclooxygenases and interleukins [29]. In addition to anti-pollution treatment, a supplementary recommendation can be used to protect the skin from potent pollution-induced damage, like using sunscreens (which can block harmful UV radiation), cleansing products (to effectively wash off pollutant particles that may be attached to the skin), or some emollients (to maintain and restore the proper function of skin barrier) [1].

3.2. Particulate Matter (PM)

PM is a category of air pollutants comprising a mixture of particles of different sizes and compositions found in the air. Some of the main sources of PM are factories, power plants, refuse incinerators, automobiles, construction activities, fires, and natural windblown dust [30-32]. Their major components are metals, organic compounds, materials of biological origin, ions, reactive gases, and the particle carbon core [5]. Some particles, which can be seen with the naked eye, such as dust, dirt, or smoke, and some others, can only be detected with high-resolution microscopes due to their smaller size. Particles that can cause pollution are divided into two categories: PM2.5 (containing fine inhalable particles of $\leq$2.5 micrometres in diameter) and PM10 (where inhalable particles are $\leq$10 micrometres in diameter).

Very small particles which exist in the nano range, especially those generated from automobile traffic sources, are considered the most hazardous components of PM since their physicochemical properties can make them highly reactive when attached to biological surfaces and possess the ability to promote oxidative stress [4], which eventually contributes to extrinsic skin ageing [8]. The hypothesised mechanism is when heavy metals and organic molecules adsorb on the particles and deposit on human skin surfaces, where they contribute to and lead to the formation of ROS like free radicals (Fig. **3**). This action may even result in skin problems like skin dryness, skin ageing, and irritation [4].

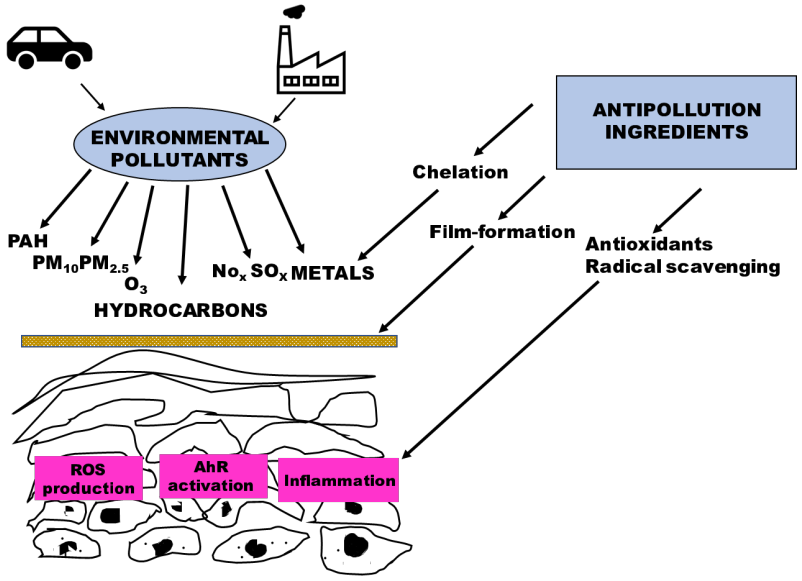

Fig. (2). Air pollutants containing various gases and particles causing skin damage *via* reactive oxygen species, aryl hydrocarbon receptor (AhR) activation, and inflammation. Anti-pollution ingredients with different strategies, including chelating agents, film-forming actives, and antioxidant radical scavengers, are employed to curb skin damage from such pollutants [27]. (*A higher resolution/colour version of this figure is available in the electronic copy of the article*).

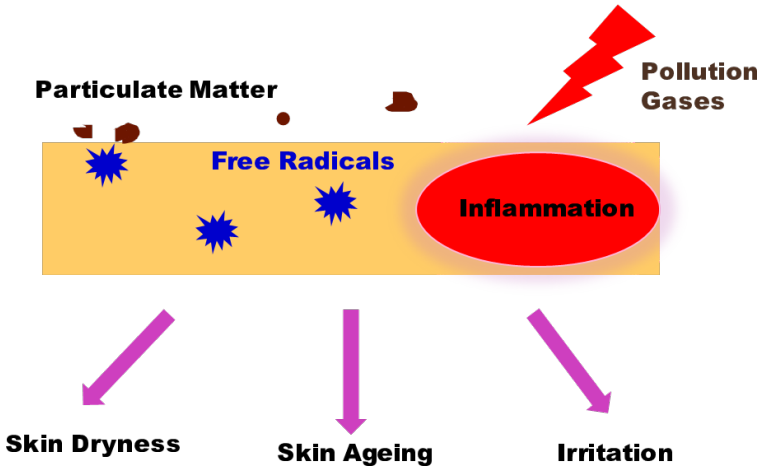

Fig. (3). Mechanistic ways of action of particulate matter causing skin damage, including skin dryness, skin ageing, and irritation *via* free radical formation and inflammation. (*A higher resolution/colour version of this figure is available in the electronic copy of the article*).

3.3. Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs and especially PAH benzopyrenes are well-known pollutants [6], which usually derive from anthropogenic activities, like the combustion of organic matter and smoke, including cigarettes, wood-burning, fuels, and exhaust fumes [33]. They can make bonds on the surface of PM and be suspended in the air along with them [34]. Additionally, they can be converted into quinones (redox-cycling chemicals that produce ROS) [35] and can also be adsorbed on the surface of PM, making it toxic. Exposure to PAHs may lead to oxidative stress and skin ageing and usually occurs due to trans-epidermal absorption or through hair follicles [36]. Moreover, PAHs can also lead to acneiform eruptions (formation of acne vulgaris, perioral dermatitis, rosacea, and folliculitis) [37]. A lipophilic compound 2,3,7,8-tetrachlorodibenzo-p-dioxin can be produced by burning (waste incineration, metal production, fossil fuel, and wood combustion), known to be the most potent member of the group of PAHs. It is more dangerous as it possesses a long half-life (5-10 years) and may also exert many biological effects as it can bind to intracellular aromatic hydrocarbon receptors.

4. FEW ACTIVE INGREDIENTS IN COSMETIC PRODUCTS

Active ingredients in cosmetic products are ingredients with specific properties and are usually used in small quantities. Depending upon their action and origin, they are divided into several categories (Table **1**). A true anti-pollution product should have more than one line of defence against skin pollution particles. Effects like film-forming, moisturising, enhancing the skin barrier, pollution particle neutralising, or preventing particles from settling on the skin would be the most desirable for these ingredients (Fig. **4**). These abilities are proven to protect epidermal cells from many hazards and risks.

5. ANTI-POLLUTION SKINCARE STRATEGIES TESTING

The protection of human skin against pollution particles is a matter of great concern. Consequently, numerous strategies have been adopted to remedy this using the aid of active ingredients in cosmetic products. An effective cleansing treatment of the skin or products containing ingredients that can form a protective film or

Table 1. Categories of anti pollutants and their mechanisms of action.

Mechanism	Anti-pollution Effect	Refs.
Film-former agent on skin epidermis.	A shield skin barrier protects against atmospheric pollution and PMs.	[25]
Barrier formation between the skin and harmful ambient substances.	Prevent the accumulation of pollution particles in the epidermis.	[7]
Skin hydration and free radical neutralisation in the cellular system.	Antioxidant activity. Reduce the levels of ROS, DNA, protein, and lipid damage.	[38]
Water-binding properties and good soothing ingredients.	Binding to pollution particles and neutralising them.	[39, 40]
Collagen synthesis stimulation.	Adjust the epidermis maturation and restores the epidermis integrity.	[39, 40]
Reduction in the activity of the enzymes that break down elastin.	Improve the skin's natural elasticity and strength.	[39-42]
Chelation - Heavy metal scavenging.	Elimination of heavy metals and boost the performance of antioxidants.	[41, 42]

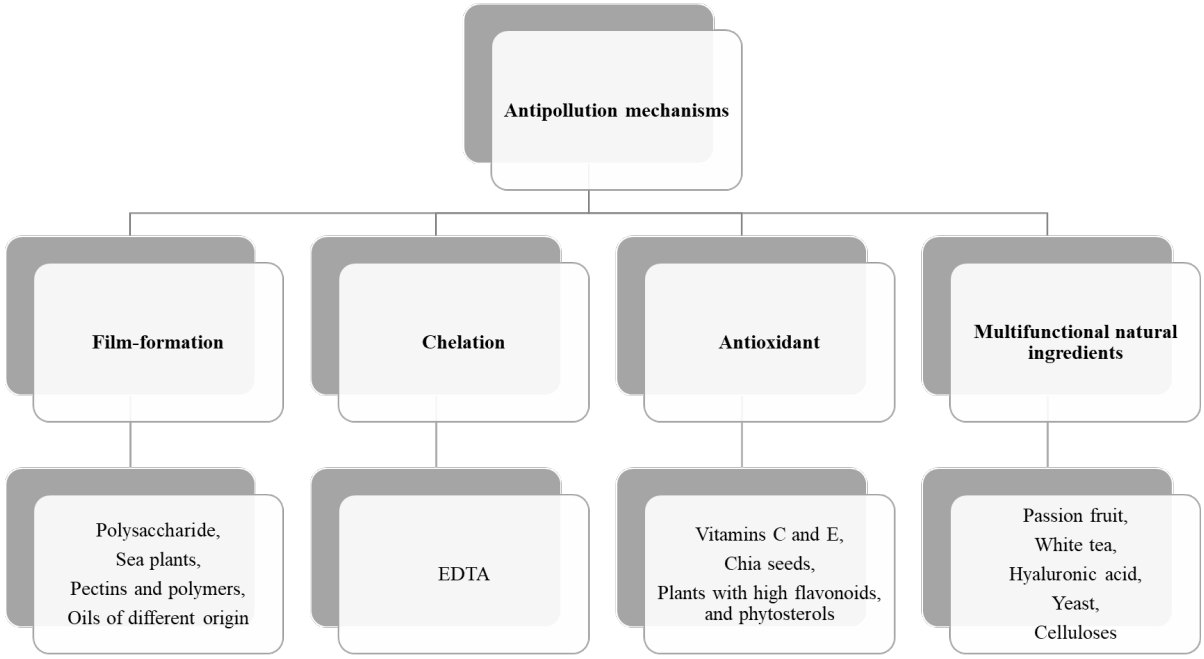

Fig. (4). Examples of anti-pollution active ingredients and their mechanisms of action. (*A higher resolution/colour version of this figure is available in the electronic copy of the article*).

antioxidants that protect against free radicals is the essential building block for protecting the skin from environmental pollution.

5.1. The Phytantriol Test

Phytantriol is alcohol widely used as a humectant in many cosmetic formulations. Formulation containing this ingredient is applied to the sample to assess its anti-pollution efficacy on reconstructed-skin cells. Moreover, some combustion residues are introduced into the samples after being radiolabelled with C-14. The outcome showed that the number of residue particles remaining was much lower after cleansing. This occurs because of phytantriol's ability to inhibit the penetration of such particles into the inner layers of the skin [25, 43].

5.2. The Mixture of Pollutants Test

This test is important to evaluate the potential anti-pollution ability of two different actives alone or in combination (*e.g.*, the Dead Sea minerals and an anionic polysaccharide). Two models were studied employing reconstructed epidermis: firstly, a mixture of pollutants (MOP) containing PM and heavy metals, and secondly, ozone exposure. It is biologically known that prostaglandin E2 (PGE2) and interleukin 1α (IL-1α) are two possible markers of inflammation, so their levels in the reconstructed skin were measured after applying minerals from the Dead Sea and an anionic polysaccharide alone or in combination. Both models demonstrated that when the active ingredients were combined, they could effectively inhibit the promotion of PGE2 and IL-1α [25].

5.3. Ellagic Acid Test

Polycyclic Aromatic Hydrocarbons (PAHs) and heavy metals are pollutant factors that can pass through keratin proteins and promote the generation of oxidative stress and cell death. Additionally, PAHs appear to present carcinogenic activity, making them extremely hazardous to human health. A polyphenol named ellagic acid was proposed to be used as a topical cosmetic anti-pollution agent. For this test, a monolayer culture of human keratinocytes was used, and many formulations of different concentrations of ellagic acid were prepared. The outcomes of this assessment showed that ellagic acid could effectively defend against environmental pollutants and combustion residues due to its cytoprotective and antioxidant capabilities. The fact that it could trap a very high number of PAHs and heavy metals made it a great

active ingredient in anti-pollution formulations. Also, the results showed that the ability of PAHs to bind to keratinocytes was increased and that it resulted in an increase in cell viability [44].

5.4. Cleansing Sonic Brush

A mixture called Sebollution was prepared for this test. It contained human sebum and PM with absorbed pollution particles. It was used to effectively mimic a model in which PM is trapped in sebum and its oils to evaluate the level of pollution of two cleansing tools: manual cleansing and a sonic brush [45]. Sebollution was applied to both cheeks of some volunteers, and then with the photographic image analysis, the cleansing ability of those two tools was assessed. One cheek was manually cleansed for five seconds with a specific amount of water and a cleansing gel. Then, the other cheek was cleansed using the sonic cleansing device for the same amount of time, with the same amount of water and gel. In both methods, photographs were taken before and after using the mixture and post-cleansing. The results showed that the concentration of Sebollution that remained after applying the manual cleanser was much higher than with the sonic brush.

6. ANTI-POLLUTION EFFECTS OF COSMETIC INGREDIENTS

6.1. Film-forming Properties

A broad class of active ingredients known to be used in cosmetic products possess film-forming properties. They can create a protective barrier around human skin that prevents pollution particles from penetrating the stratum corneum and reaching the inner cells. Their mechanistic way of action is shown in Fig. (**5**). The cosmetic formulation is applied and evenly distributed on the skin's surface. Following this, the solvent begins to evaporate, and as long as this procedure takes place, the molecules of the film-forming agent interact amongst themselves to create a very thin complex, which completely attaches to the skin [46]. Many ingredients possess film-forming abilities and are known for forming protective barriers against environmental hazards. Moreover, this thin film enhances its skin-protective ability by reducing transepidermal water loss (TEWL). Emollients are a category of ingredients observed to prove this theory [27] in a study conducted where the amount of TEWL was measured after treating the skin with ceramide emollient for four weeks. The results were encouraging, as a decent decrease was observed [47]. The same procedures were also followed by subsequent studies, with the only difference being that the levels of TEWL were measured after chronically applying emollients on atopic skin. These results also showed a reduction [48].

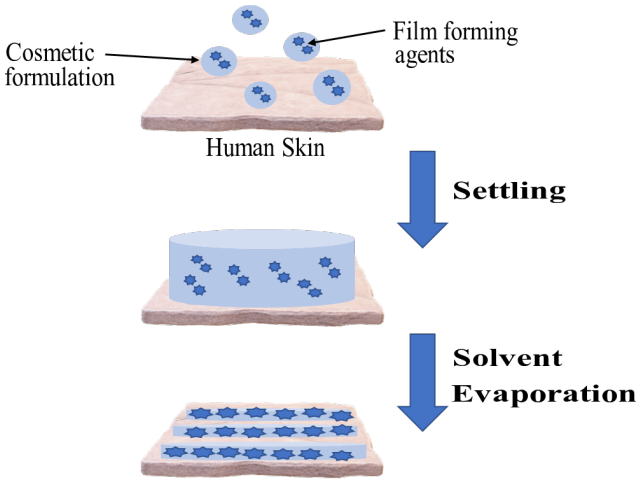

Fig. (5). Mechanism of action of film-forming agents. (*A higher resolution/colour version of this figure is available in the electronic copy of the article*).

Polysaccharides are a class of carbohydrates composed of many monosaccharide chains linked to each other (*via* o-glycosidic linkages). Their properties derive from the presence of substituent groups (either natural or seminatural) connected to these monosaccharides. Therefore, natural and seminatural polysaccharides can be divided into five main categories according to their charges, including anionic, cationic, non-ionic, amphoteric, and hydrophobic [49]. Cellulose gum (carboxymethylcellulose) and carboxymethyl chitin [49], as well as some other well-known polysaccharides like alginate, pectin, and chitosan, are mainly chosen in cosmetic formulations due to their rheological abilities/properties in many different applications [50]. Moreover, some sea plants like *Klebsiella pneumoniae* and *Myrtus communis* extracts, and other similar plant extracts are commonly used due to their polysaccharide structure and protective effects on the skin. Another important category of polysaccharides derived from marine brown algae and bacterial fermentation is alginates. They consist of two types of monosaccharides (*i.e.*, β-D (1,4)-mannuronic acid and α-L-(1,4)-guluronic acid) and possess the ability to form a gel (which can be stronger or weaker based on the ratio of these monosaccharides), and hence protect skin from external factors [51]. Pectins can be found and extracted from citrus fruit peels, provide cellular support, and enhance skin barrier function. They are composed of repeating units of α-D-(1,4)-galacturonic acid with additional connected units of α-L-(1,2)-rhamnose. Due to their citrus source, pectins are used for low pH formulations [49]. Carrageenans are cellular structural polysaccharides with anionic characteristics isolated from marine red algae. Carrageenans are large, highly flexible molecules that curl to form helical structures. This phenomenon gives them the ability to form gels at room temperature and therefore are widely used as a thickening and stabilising agent, not only in food but in other industries as well. Their biggest advantage, which promotes their usage, is the reduced thickness under shear stress and the ability to recover their viscosity once the stress is removed. This means that they are easy to pump but stiffen again afterward. They are appropriate for topical formulations as they are very abundant in polysaccharides, are biocompatible, and possess stabilising and thickening properties, with a high capacity of water retention and mechanical strength of gels. A film-forming polymer named Brassica Campestris and Aleurites Fordii Oil Copolymer is made from Tung (China wood) and rapeseed oil and has the ability to form a long-lasting coating layer over the skin, delivering advanced protection from the damage caused by many environmental threats. A study conducted by TRI-K [52] demonstrated that this active ingredient showed a 32% improvement in skin protection from PM. An active ingredient blend consisting of lecithin, acrylic acid/acryl amidomethyl propane sulfonic acid copolymer dimethyl methoxy chromanol, glyceryl caprylate, and diisopropyl adipate showed the ability to provide a barrier between skin and many harmful compounds and can amplify the prevention of the accumulation of pollution particles on the skin. Furthermore, this blend contains metal chelating properties resulting in higher resistance to protect against skin damage from heavy metals [7].

Algae are also a source of naturally derived ingredients, and their extracts are commonly used in many formulations. Nannochloropsis Occulata is an alga that contains high volumes of vitamin C, vitamin B12, and polysaccharides. Its main function is the skin firming effect, forming a thin film and preventing particle penetration. It is also used to repair and maintain skin cells and promote collagen stimulation, a fundamental part of the skin's connective tissue, and offers long-term resistance [53]. Protectami® is a 100% natural purified extract of Padina Pavonica, a brown alga from the Mediterranean Sea, with glycerine. It improves skin resistance by ensuring skin cell cohesion. This is achieved by stimulating calcium-dependent cell structure synthesis and enhancing skin protection even in polluted environments.

6.2. Chelation

Heavy metals can penetrate the cell membrane and be stored in the cytoplasm, disrupting membrane permeability and the function of cell organelles. Therefore, in any therapeutic approach, special attention should be paid to the diagnosis and detoxification from heavy metals, chemicals, and toxins. A good method of detoxifying our body is chelation (demineralization). It essentially describes how a chelating agent adheres to certain metals and forms a complex followed by their elimination from the body. Chelating agents are compounds that bind to metal ions and play a key role in the stability and effectiveness of cosmetics. The chelation process stabilises the metal ions by preventing them from reacting chemically with other substances [54]. Therefore, their anti-pollution effect takes the form of heavy metal scavenging. The most common chelating agent used is ethylene diamine tetra-acetic acid (EDTA) [55], but there are some new actives in the market like DETOXYL®, which can efficiently protect the skin against urban pollutants like nicotine, lead, chlorine, and exhaust gases [56]. There are also some naturally-derived biodegradable chelating agents named Dermofeel®PA and Dermofeel®PA-3, which can be used as alternatives to EDTA, which may deactivate metal ions by forming a complex between the chelator and the metal [57].

6.3. Antioxidant Ability

PM and other environmental pollutants can induce oxidative stress and promote the generation of ROS and mostly free radicals, which can damage cell proteins, DNA, and cell membranes. This damage results in many problems, including tissue damage and the production of wrinkles and fine lines. Therefore, the active ingredients with antioxidant activity and metal chelating agents in cosmetic products can counter such effects. Vitamins C and E are commonly known to reduce the levels of ROS, as well as damage DNA, protein, and lipid [58] by donating an electron to ROS, which results in its elimination. Vitamin E is actually divided into tocopherols and tocotrienols. Tocopherol was found to obtain antioxidant properties as it protects cell membranes from lipid peroxidation by free radical scavenging [59]. Vitamin C is a powerful antioxidant as it can neutralise free radicals by acting on peroxyl radicals or by boosting the antioxidant properties of vitamin E. Thus, lipid peroxidation can easily be controlled in the cellular membranes [60]. Additionally, the ability of Vitamin C to effectively hinder the active site of tyrosinase, which is acquainted with being an enzyme that can restrict melanogenesis, makes it a highly efficient factor for treating diseases such as melasma, hyperpigmentation, and sunspots. Tyrosinase can catalyse the hydroxylation reaction of tyrosine which produces 3,4-dihydroxyphenylalanine and a precursor compound of melanin [61]. Except naturally derived antioxidants, some actives can also be found in minerals like a copper-rich pollution magnet extracted from malachite. This innovative active offers antioxidant activity, increases the efficacy of cellular protection systems and protects against oxidative stress [62].

Salvia Hispanica (chia) seed extract contains many nutrients, like phytosterols, flavonoids, alpha lipolytic acid, coumaric acid, caffeic acid, and tocopherols, which provide antioxidant properties. This may aid skin protection from ROS and accelerate repair systems to avoid more damage. Chia oil can also provide better skin hydration, which reduces trans-epidermal water loss and enhances skin barrier function [63]. Camellia Sinensis (white tea) extract and its high flavonoid content can neutralise 80% of free radicals, effectively protect cell membranes, and defend the skin against pollution and environmental hazards [10]. Moreover, the myrtle leaf extract is rich in many hydro-soluble flavonoids, resulting in effective antioxidant properties and skin protection abilities. It can also neutralise some of the effects of environmental pollutants and free radicals [9]. Active flavanols, phyto antioxidants, quercitrin, and miquelianin can be found in the pink pepper solution derived from the Schinus Molle tree. Control of antioxidant enzymes can protect cells from oxidative stress induced by dust particles in the environment. Another anti-pollution function it possesses is reducing skin permeability and increasing hydration levels of the stratum corneum [64].

6.4. Multifunctional Natural Ingredients

Recently, there has been an ever-growing trend in the skincare market, none other than the use of multifunctional products. Consumers seek to simplify their skincare regime, and products with many properties seem to be ideal for this purpose. Anti-pollution products can tap into well-established global consumer demand for anti-ageing, skin lightening, and suncare products. Passiflora Edulis fruit extract is rich in polyphenols, harnessing the hormesis pathway by activating the natural self-defence systems and preventing the deleterious effects of indoor and outdoor pollutants by free radical scavenging. Among its beneficial effects are the detoxification and protection of the skin from the strong stresses of environmental pollutants, restoration and prevention of the degradation of the essential components of the skin barrier, and extracellular matrix preserving the barrier function [65]. Similarly, the extract of Marrubium Vulgare, also known as Horehound, protects from the penetration of pollutants into the skin cells while also positively impacting the fight against free radicals. Additionally, it is also claimed to support the removal of toxic oxidant species and fight oxidative stress while protecting, strengthening, repairing skin, and reducing inflammation [66].

Paeonia Albiflora root extract, rich in oligosaccharides, is known for fighting premature ageing by regulating cellular communication. It provides gradual replumbing, volumising, and firming by controlling communication and limiting negative proinflammatory exchanges between the dermis and hypodermis. In addition, it increases the thickness and volume of the adipose tissue [39]. White Tea extract bullet-proofs the structural proteins of the skin. White tea extract not significantly reduces the activities of the enzymes, which are responsible for elastin and collagen breakdown, but it also improves the natural elasticity and strength of the skin [40]. Moreover, an extract from the root of Astragalus Membranaceus, Atractylodes Macrocephala, and Bupleurum Falcatum has shown numerous positive effects, including adjustments in epidermis maturation, restoration of epidermis integrity, stimulation of collagen synthesis, resistance against the melanogenesis, and the oxidative stress from UV radiations and pollution [67]. Except for multifunctional ingredients, mixtures of actives are also well known in many skincare products. A mixture of Salvia Hispanica seed extract, trehalose, galactoarabinan, glycerin, xylitol, sodium phosphate, and sorbitol provides an excellent defence against pollutant particles and prevents the penetration of many polluting agents by a percentage of 65%. In addition to that, it protects cells against ageing and acts as an anti-inflammatory agent [7].

Chitin, chitosan, hyaluronic acid, and celluloses are known to possess multifunctional properties, and that is why these are so commonly found in many cosmetic products, playing a pivotal role in the research and development of cosmetics products. According to some of the main effects of polysaccharides (like film-forming and moisturising), they can increase the ability to prevent penetration of pollutant particles, fortify the skin barrier, and improve skin hydration. Moreover, polysaccharide-based formulations promote the reduction of trans-epidermal water loss, as they can absorb moisture from the surrounding environment and effectively hydrate the skin, which also protects and maintains the skin barrier function. Chitosan has been widely reported for its use in topical and transdermal delivery systems, largely due to its nontoxicity and susceptibility to degradation. In addition, chitosan can improve the penetration ability across the skin, mainly because it can alter the structure of keratin [68, 69]. Chitosan can also increase the water content of the stratum corneum and cell membrane fluidity. Apart from chitosan itself, its derivatives have also been verified to improve the water content of the stratum corneum.

CONCLUSION

Considering that skin is the largest organ of the human body, and due to its exposure to environmental hazardous pollution agents, there is a rising urge for cosmetic formulations to cope with this problem. As many ingredients with various abilities, such as film-forming properties and reducing enzymatic activity, aid in skin shielding and disallow particles from interacting and being absorbed by the skin, they reduce the amount of ROS (which may harm lipids, proteins, and DNA), promote hydration of epidermal cells, boost collagen synthesis or stimulate calcium, and improve skin resistance by retaining its integrity and cell cohesion. Incorporating such ingredients into cosmetic products elevates their resistance to the external environment of air pollution while maintaining the multifunction properties on the skin in a broader context. Future work will compare the effectiveness of cosmetic products containing different ingredients against pollution and their impact on the skin.

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CONFLICT OF INTEREST

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