WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
Coden USA: WJPRAP Impact Factor 8.63
Volume 15, Issue 10, 177-186. Review Article ISSN 2277–7105

ROLE OF NATURAL ANTIOXIDANTS IN ANTI-POLLUTION SKINCARE: A COMPREHENSIVE REVIEW

***[1]Miss. Riya R. Sondhiya, [2]Dr. Sana Ahmed**

[1]Post Graduate Student, Department of Cosmetic Technology; LAD & Smt. RP College for Women, Seminary Hills Nagpur.

[2]Guide, Department of Cosmetic Technology; LAD & Smt. RP College for Women, Seminary Hills Nagpur.

Article Received on 16 April 2026,
Article Revised on 06 May 2026,
Article Published on 16 May 2026,

https://doi.org/10.5281/zenodo.20199006

***Corresponding Author**

Miss. Riya R. Sondhiya

Post Graduate Student, Department of Cosmetic Technology; LAD & Smt. RP College for Women, Seminary Hills Nagpur.

How to cite this Article: *Miss. Riya R. Sondhiya, Dr Sana Ahmed. (2026). Role Of Natural Antioxidants In Anti-Pollution Skincare: A Comprehensive Review. World Journal of Pharmaceutical Research, 15(10), 177–186.

ABSTRACT

Pollution is becoming increasingly evident owing to rapid urban development and an increase in the number of industries that produce pollutants. Various pollutants, such as particulate matter, gases, and metals, can penetrate the skin and cause organ damage through free radical generation via various methods, including oxidation, inflammation, ageing, and uneven melanin distribution. Consequently, the need for anti-pollution agents, particularly antioxidants that eliminate free radicals, has increased significantly. This review describes the mechanisms of action of five antioxidants, including green tea, turmeric, vitamin C, vitamin E, and butterfly pea flower, in protecting the skin against pollutants. Articles were found in various databases, such as PubMed, Google Scholar, and Science Direct, involving experiments conducted both in vitro and in vivo in humans. Hence, these antioxidants have protective properties and can be used independently or in combination to enhance the efficacy of anti-pollution products.

KEYWORDS: anti-pollution skincare, plant-based antioxidants, ROS, Camellia sinensis, curcumin, ascorbic acid, tocopherol, butterfly pea flower, particulate matter, oxidative stress, skin barrier.

1. INTRODUCTION

The skin, the largest organ of the human body, functions as a protective barrier that separates internal tissues from the external environment. Increasing environmental pollution has resulted in continuous exposure of the skin to harmful pollutants.

Over the past few decades, industrial activities, vehicle emissions, and urban expansion have significantly increased pollution levels, particularly in densely populated regions. Air pollution mainly consists of gases such as nitrogen oxides, ozone, and carbon monoxide, along with particulate matter, such as PM10 and PM2.5. These tiny particles can penetrate the skin through the pores and hair follicles. Once inside, they generate reactive oxygen species that damage skin cells, break down collagen, and trigger inflammation. This leads to visible effects such as wrinkles, pigmentation, and loss of elasticity, as well as skin conditions such as acne and eczema.

In response to these mounting concerns, growing awareness of these effects has increased the demand for anti-pollution skincare products, particularly those based on natural ingredients such as plant extracts. Natural antioxidants, such as green tea, turmeric, vitamin C, vitamin E, and butterfly pea flower, are known for their ability to neutralise free radicals, reduce inflammation, and protect skin structure. This review discusses the mechanisms and applications of these ingredients in skin care.

2. OVERVIEW OF SKIN–POLLUTION INTERACTION

The outermost layer of the skin, known as the stratum corneum, is the first point of contact with environmental pollutants. Although it provides some level of protection, very small particles can still penetrate through the skin via intercellular spaces, hair follicles, and sweat glands. Once these pollutants enter the skin, they trigger several harmful processes.

One of the main effects is oxidative stress, where reactive oxygen species are produced and begin to damage lipids, proteins, and DNA within skin cells. In addition, certain pollutants activate cellular pathways that increase the production of toxic compounds, further enhancing damage. Pollution also leads to inflammation by stimulating the release of inflammatory mediators, which break down collagen and elastin, resulting in premature ageing.

Furthermore, pollutants can weaken the skin barrier, leading to moisture loss, dryness, and increased sensitivity. They can also oxidise natural skin oils, producing substances that

contribute to acne and irritation. To counter these effects, skincare strategies such as protective barrier formation, deep cleansing, and the use of antioxidants have been developed. Among these, antioxidant-based approaches are considered the most effective, especially when natural ingredients are used.

3. SEARCH METHODOLOGY

This review was conducted by collecting and analysing information from various reliable scientific sources. Data was obtained from well-known databases such as PubMed, Google Scholar, Science Direct, Scopus, and Web of Science.

Specific keywords related to anti-pollution skincare and natural antioxidants were used to identify relevant studies. Only peer-reviewed articles, review papers, and books published in English were included. The selected studies focused on the role of natural antioxidants in protecting the skin from pollution-related damage. Different types of research were considered, including laboratory studies, animal experiments, and clinical trials involving human participants.

Most of the studies were published between 2000 and 2025, although some older references were included for foundational understanding. The collected data were carefully evaluated to provide a clear understanding of the effectiveness of these antioxidants.

4. NATURAL ANTIOXIDANTS IN ANTI-POLLUTION SKINCARE

4.1. Green Tea — Camellia sinensis

Green tea, obtained from the plant Camellia sinensis, is rich in catechins, especially epigallocatechin gallate (EGCG), which is known for its strong antioxidant activity. These compounds help neutralize free radicals, reduce inflammation, and protect collagen from degradation. Green tea also supports the skin’s natural defense system and can bind harmful metals present in pollutants. Due to these benefits, it is widely used in skincare products such as serums, moisturizers, and sunscreens, although stability issues are addressed using modern formulation techniques like encapsulation.

Camellia sinensis.

4.2. Turmeric and Curcumin — Curcuma longa

Turmeric, derived from Curcuma longa, contains curcumin as its main active compound. Curcumin exhibits strong antioxidant and anti-inflammatory properties by neutralizing reactive oxygen species and reducing inflammatory responses. It also supports the skin's defense system and helps prevent collagen breakdown. Despite challenges like low solubility and instability, advanced delivery systems such as nanoparticles have improved its effectiveness in skincare products, particularly for acne, pigmentation, and skin repair.

Turmeric.

4.3. Vitamin C — Ascorbic Acid

Vitamin C, also known as ascorbic acid, is a water-soluble antioxidant essential for skin health. It plays a key role in collagen synthesis, protects against oxidative stress, and helps reduce pigmentation. It is particularly effective against pollutants like ozone and works by neutralizing free radicals. However, due to its instability, stable derivatives are commonly used in cosmetic formulations. Vitamin C is widely used in serums and anti-aging products

and is often combined with Vitamin E for enhanced protection.

Ascorbic Acid.

4.4. Vitamin E — Tocopherol

Vitamin E is a fat-soluble antioxidant that protects the skin's lipid layer and cell membranes from oxidative damage. It is present in the outer layer of the skin and acts as a first line of defense against pollutants. Vitamin E works by preventing lipid peroxidation and reducing inflammation. It also works synergistically with Vitamin C, which helps restore its active form. It is commonly used in moisturizers, sunscreens, and oil-based products.

Tocopherol.

Butterfly Pea Flower — Clitoria ternatea

Butterfly pea flower, obtained from Clitoria ternatea, contains anthocyanins known as ternatins, which provide strong antioxidant activity. These compounds help neutralize free radicals, reduce inflammation, and protect collagen and elastin. The plant also contains flavonoids that support skin health. Its stability and natural color make it attractive for cosmetic use, and it is increasingly included in serums, masks, and anti-aging products.

Clitoria ternatea.

COMPARATIVE SUMMARY

Ingredient	Plant Source	Active Constituents	Principal Mechanism(s)	Main Pollutant Targets	Typical Cosmetic Uses
Green Tea	*Camellia sinensis (Theaceae)*	EGCG, ECG, EGC, EC; quercetin, kaempferol glycosides	ROS scavenging; NF- κB & AhR inhibition; Nrf2/HO-1 induction; MMP suppression; metal chelation	PM2.5, PAHs, ozone, UV	Serums, moisturizers, sunscreens, anti-aging creams
Turmeric/ Curcumin	*Curcuma longa (Zingiberaceae)*	Curcumin, demethoxycurcumin, bisdemethoxycurcumin; ar-turmerone	NF-Kb & ERK inhibition; Nrf2/HO-1 activation; GSH upregulation; metal chelation; MMP inhibition	PM10/PM2.5, combustion particulates, VOCs	Anti-acne formulations, brightening/depigmenting serums, anti-inflammatory creams
Vitamin C	Citrus spp., rose hip; also synthetic for cosmetics	L-Ascorbic acid; SAP, MAP, AA-2G, EAC (stable derivatives)	Water-phase ROS scavenging; tocopherol regeneration; collagen cofactor; melanin pathway inhibition	Ozone, NO2, PM- derived radicals, UV	Brightening serums, anti-aging products, anti-pollution shields, spot treatments
Vitamin E	Wheat germ, sunflower, nut oils; tocopheryl acetate (synthetic)	α-Tocopherol, tocopheryl acetate; tocotrienols	Lipid-phase radical chain interruption; sebum surface protection; PKC inhibition; Vitamin C synergy	Ozone (squalene/surface lipid oxidation), PM membrane damage, UV-B	Moisturizers, sunscreens, eye creams, barrier repair formulations, hair care
Butterfly Pea Flower	*Clitoria ternatea (Fabaceae)*	Ternatins (polyacylated delphinidin anthocyanins),	Broad ROS scavenging; AhR/CYP1A1	PAHs, PM2.5, NO2, ozone, heavy metals	Anti-aging serums, face mists, brightening masks, pH-sensitive color

		quercetin, kaempferol, proanthocyanidins	suppression; NF-κB inhibition; Nrf2 activation; anti-collagenase/elastase		cosmetics

5. COMBINING ANTIOXIDANTS: THE CASE FOR MULTI-INGREDIENT FORMULATIONS

Natural antioxidants are more effective when used together, as they can protect different parts of the skin. For example, Vitamin C and Vitamin E form a well-known combination where Vitamin C helps regenerate Vitamin E after it neutralizes free radicals. This enhances their overall effectiveness. Green tea can further support this combination by improving antioxidant activity, while curcumin adds strong anti-inflammatory effects. Butterfly pea flower contributes additional stability and antioxidant strength. Modern skincare formulations often combine multiple antioxidants and use advanced delivery systems to improve their stability and absorption, providing better protection against pollution.

From a practical formulation perspective, layering strategies make sense. A morning serum containing Vitamin C, green tea catechins, and butterfly pea flower extract addresses aqueous-phase ROS and provides melanin suppression. An SPF moisturizer containing Vitamin E and curcumin nanoemulsion addresses lipid-phase protection and provides the anti-inflammatory backing that sunscreens alone cannot offer. This kind of layered approach is increasingly standard in premium anti-pollution skincare lines and is supported by the mechanistic logic developed over the research reviewed here.

6. DISCUSSION

The antioxidants reviewed in this article demonstrate strong potential in protecting the skin from pollution-related damage. They work by reducing oxidative stress, controlling inflammation, and supporting the skin's natural defense mechanisms. While each antioxidant has its own specific function, their combined use offers a more complete protective effect.

However, most available studies are based on laboratory or controlled conditions, and there is a need for more real-world clinical research to fully understand their long-term effectiveness. Future studies should focus on human trials, improved delivery systems, and standardized methods for evaluating pollution-related skin damage.

7. CONCLUSION

Air pollution has become a major factor affecting skin health, leading to oxidative stress,

inflammation, and premature aging. Natural antioxidants such as green tea, turmeric, vitamin C, vitamin E, and butterfly pea flower provide effective protection against these harmful effects.

They work through multiple mechanisms, including neutralizing free radicals, reducing inflammation, and strengthening the skin barrier. When used together, they offer enhanced protection and are highly suitable for modern anti-pollution skincare formulations. With increasing demand for natural and effective products, these antioxidants play an important role in the development of future skincare solutions. However, further research is needed to confirm their long-term benefits under real-life conditions.

8. REFERENCES

1. Kampa M, Castanas E. Human health effects of air pollution. Environ Pollut., 2008; 151(2): 362-367.
2. Krutmann J, Liu W, Li L, Pan X, Crawford M, Sore G, Seite S. Pollution and skin: From epidemiological and mechanistic studies to clinical implications. J Dermatol Sci., 2014; 76(3): 163-168.
3. Juliano C, Magrini GA. Cosmetic functional ingredients from botanical sources for anti-pollution skincare products. Cosmetics, 2018; 5(1): 19.
4. Vierkotter A, Schikowski T, Ranft U, Sugiri D, Matsui M, Kramer U, Krutmann J. Airborne particle exposure and extrinsic skin aging. J Invest Dermatol., 2010; 130(12): 2719-2726.
5. Shukla VKS, Lad V. Antioxidant and anti-inflammatory benefits of Curcuma longa in human wellness. J Food Technol Pres., 2022; 4(2): 129.
6. Kim KE, Cho D, Park HJ. Air pollution and skin diseases: Adverse effects of airborne particulate matter on various skin diseases. Life Sci., 2016; 152: 126-134.
7. Pham DM, Boussouira B, Moyal D, Nguyen QL. Oxidization of squalene, a human skin lipid: A new and reliable marker of environmental pollution studies. Int J Cosmet Sci., 2015; 37(4): 357-365.
8. Afaq F, Abu Zaid M, Pelle E, Khan N, Syed DN, Matsui MS, Maes D. Aryl hydrocarbon receptor is an ozone sensor in human skin. J Invest Dermatol., 2009; 129(10): 2396-2403.
9. Valacchi G, Sticozzi C, Belmonte G, Cervellati F, Demaude J, Chen N, Krol Y, Oresajo C. Vitamin C compound mixtures prevent ozone-induced oxidative damage in human keratinocytes. PLoS ONE, 2015; 10(6): e0131097.

10. Hewlings SJ, Kalman DS. Curcumin: A review of its effects on human health. Foods, 2017; 6(10): 92.
11. Vollono L, Falconi M, Gaziano R, Iacovelli F, Dika E, Terracciano C, et al. Potential of curcumin in skin disorders. Nutrients, 2019; 11(9): 2169.
12. Kim JS, Oh JM, Choi H, Kim SW, Kim BG, et al. Activation of the Nrf2/HO-1 pathway by curcumin inhibits oxidative stress in human nasal fibroblasts exposed to urban particulate matter. BMC Complement Med Ther., 2020; 20: 289.
13. Sikora E, Scapagnini G, Barbagallo M. Curcumin, inflammation, ageing and age-related diseases. Immun Ageing, 2010; 7: 1.
14. Thiele JJ, Traber MG, Podda M, Tsang K, Cross CE, Packer L. Ozone depletes tocopherols and tocotrienols topically applied on murine skin. FEBS Lett., 1997; 401(2-3): 167-170.
15. Poljsak B, Dahmane R. Free radicals and extrinsic skin aging. Dermatol Res Pract., 2012; 2012: 135206.
16. Katiyar SK. Skin photoprotection by green tea: Antioxidant and immunomodulatory effects. Curr Drug Targets Immune Endocr Metabol Disord, 2003; 3(3): 234-242.
17. Chen L, Mo H, Zhao L, Gao W, Wang S, Cromie MM, et al. Therapeutic properties of green tea against environmental insults. J Nutr Biochem., 2017; 40: 1-13.
18. Weber SU, Thiele JJ, Cross CE, Packer L. Vitamin C, uric acid and glutathione gradients in murine stratum corneum and susceptibility to ozone exposure. J Invest Dermatol., 1999; 113(5): 1128-1132.
19. Nair S, Nair R. Clitoria ternatea: Biochemical and pharmacological review. Asian Pac J Trop Biomed., 2014; 4(S2): S1-S4.
20. Deng H, Wan M, Li H, Chen Q, Li R, Liang B, et al. Curcumin protection against UVA photo-damage in HaCaT cells by regulating Nrf2. Bioengineered, 2021; 12(1): 9993-10006.
21. Liu X, Zhang R, Shi H, Li X, Li Y, Taha A, et al. Protective effect of curcumin against UVA irradiation-induced photoaging in human dermal fibroblasts. Mol Med Rep., 2018; 17(5): 7227-7237.
22. Lefebvre MA, Pham DM, Boussouira B, Bernard D, Camus C, Nguyen QL. Evaluation of the impact of urban pollution on skin quality: A multicentre study in Mexico. Int J Cosmet Sci., 2015; 37(3): 329-338.
23. Blanco-Pascual N, Montero MP, Gomez-Guillen MC. Antioxidant film development from unrefined extracts of brown seaweeds Laminaria digitata and Ascophyllum nodosum.

Food Hydrocoll., 2014; 37: 100-110.

24. Pan TL, Wang PW, Aljuffali IA, Huang CT, Lee CW, Fang JY. The impact of urban particulate pollution on skin barrier function and subsequent drug absorption. J Dermatol Sci., 2015; 78(1): 51-60.
25. Ariede MB, Candido TM, Morocho Jacome AL, Robles Velasco MV, de Carvalho JCM, Baby AR. Cosmetic attributes of algae: A review. Algal Res., 2017; 25: 483-487.