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REVIEW ARTICLE

A Review on Pharmacognostic Features, Phytochemistry, and Therapeutic Potential of *Nerium oleander* L.

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Abstract: *Nerium oleander* L. (Apocynaceae) is an evergreen shrub characterized by ornamental foliage, therapeutic bioactive constituents, and profound cardiac toxicity. Native to the Mediterranean region and warm temperate zones of Asia, the species accumulates complex secondary metabolites across all anatomical organs. Cardenolides, primarily oleandrin, digitoxigenin, folinerin, adynerin, and odoroside variants, represent the central bioactive and toxic principles. These cardiac glycosides exert potent pharmacological effects through competitive inhibition of the plasma membrane Na^+/K^+-adenosine triphosphatase (Na^+/K^+-ATPase) pump, altering intracellular ion homeostasis and inducing positive inotropy alongside lethal arrhythmias at toxic concentrations. Apart from cardenolides, there are also pentacyclic triterpenes such as ursolic acid, oleanolic acid, betulinic acid, and betulin, alongside polyphenols, flavonoids including quercetin and kaempferol glycosides, and volatile monoterpenes. Pharmacognostic characterization reveals linear-lanceolate coriaceous leaves arranged in whorls of three, sunken stomatal crypts lined with protective trichomes, and laticiferous vessels containing latex. Agronomic evaluations document marked drought tolerance, adaptability to saline or nutrient-depleted soils, and optimal development under full sunlight with well-drained substrate. Pharmacological investigations establish cytotoxic activity against diverse neoplastic cell lines, antimicrobial broad-spectrum efficacy, antioxidant capacity, and anti-inflammatory action. Ethnomedicinal records indicate traditional topical applications for dermatological lesions, scabies, and localized inflammation, though systemic application remains restricted by severe toxicity. A rigorous appraisal of botanical traits, chemical constituents, toxicity pathways, and therapeutic properties elucidates the dual nature of *Nerium oleander* as both a botanical hazard and a valuable source for pharmaceutical development.

Keywords: *Nerium oleander*; Cardenolides; Phytochemistry; Pharmacognosy; Cardiac toxicity.

1. Introduction

Nerium oleander L. belongs to the family Apocynaceae and represents the sole universally accepted species within the genus *Nerium* [1]. Commonly known as oleander or rose bay, the generic name originates from the Ancient Greek word *nerion*, referring to water or damp habitats, while the specific epithet *oleander* reflects a superficial morphological resemblance of its foliage to that of the olive tree, *Olea europaea* [2]. Taxonomic historical synonyms include *Nerium indicum* Mill., *Nerium odorum* Sol., *Nerium thyrsiflorum* Salisb., and *Nerium verecundum* Salisb., which are now botanically recognized as conspecific variants or cultivars of *Nerium oleander* L. rather than distinct species [3].

A critical distinction must be established between *Nerium oleander* L. and yellow oleander, *Cascabela thevetia* (L.) Lippold (synonym *Thevetia peruviana* (Pers.) K.Schum.), which also belongs to Apocynaceae [4]. Although both plants contain toxic cardenolides and share common vernacular appellations in regional languages, they possess distinct botanical phenotypes, floral architectures, and cardenolide profiles [5]. Confusion between *Nerium* and *Cascabela* species in toxicological literature leads to misattribution of specific cardiac glycoside profiles; hence, rigorous morphological and phytochemical differentiation remains critical [6].

Due to its global distribution as an ornamental plant and its deep integration into traditional medical systems, *Nerium oleander* possesses various vernacular names across various languages and geographical regions [7]. In English, the species is known as oleander, rosebay, rose laurel, or French willow. In Sanskrit literature, it is documented as *Karaveera*, while in Hindi, Punjabi, and Urdu, it is designated as *Kaner*. Marathi literature records the plant as *Kanher*, Bengali as *Raktakarabi*, Tamil as *Sevvarali*, Telugu as *Ganneru*, Kannada as *Kanagilu*, Malayalam as *Arali*, Odia as *Konneri*, and Manipuri as *Kabirei* [8]. Internationally, Spanish-speaking regions refer to the plant as *Adelfa* or *Laurel Rosa*, French literature documents *Laurier-rose*, German resources designate *Oleanderblätter*, and Mandarin Chinese texts record *Jia Zhu Tao* [9].

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Figure 1. Flowers and Leaves of *Nerium oleander* L

Traditional health systems across Asia and the Mediterranean Basin have historically documented localized applications of *Nerium oleander* preparations [10]. Despite high intrinsic toxicity, small, calibrated doses of root or leaf extracts were used in ancient folk practice for dermatological ailments, cutaneous fungal infections, ringworm, ulcers, leprosy, malaria, and severe pain [11]. In certain historical practices, controlled preparations were investigated for cardiac stimulation, abortifacient properties, and anti-seizure remedies [12]. However, modern pharmacovigilance highlights the narrow therapeutic index of these preparations, restricting contemporary clinical focus to purified phytoconstituents and targeted cytotoxic derivatives [13].

2. Pharmacognostic and Morphological Characterization

2.1. Macroscopic Characteristics

2.1.1. Leaves

The leaves of *Nerium oleander* exhibit distinct structural adaptations suited for xeric and warm environments [14]. They are strictly simple, exstipulate, and arranged in opposite pairs or, more characteristically, in whorls of three (ternate) along the erect woody stems [15]. Foliar dimensions typically range from 5 to 21 cm in length and 1 to 3.5 cm in width. The leaf blade is linear-lanceolate with an acuminate or acute apex, an attenuated base, and an entire margin. The texture is markedly coriaceous (leathery) and thick, featuring a glossy, dark green adaxial surface and a paler, duller abaxial surface. Venation is pinnate with a prominent, pale yellow mid-rib running centrally, giving rise to numerous fine, parallel secondary veins that diverge at wide angles toward the leaf margin [16].

2.1.2. Flowers

Inflorescences are terminal, compact cymes arising at the apex of leafy branches [17]. The flowers are showy, fragrant, actinomorphic, and hermaphroditic, measuring approximately 3 to 5 cm in diameter. The calyx is deeply five-lobed with lanceolate sepals. The corolla is hypocrateriform (salverform), composed of five clawed petals that overlap to the right in the bud stage, though cultivated varieties frequently display double or semi-double floral morphology with multiple petal whorls [18]. Floral coloration spans a broad spectrum including vivid shades of pink, dark red, magenta, white, salmon, and pale yellow. A defining structural marker of the corolla throat is the presence of a delicate, fringed, crown-like corona consisting of five appendage scales that extend inward, forming an internal floral tube [19].

2.1.3. Stem, Fruit, Root, and Seed Characteristics

Nerium oleander grows as an erect, multi-stemmed, evergreen shrub or small tree reaching heights of 2 to 6 meters with an upright, spreading habit [20]. Young stems are flexible, smooth, cylindrical, and glaucous with a bluish-white cast, exuding a viscous white latex upon mechanical injury. Mature stems transition to greyish-brown, woody, and lightly fissured bark [21].

The fruit develops as a pair of narrow, elongated, cylindrical, erect follicles measuring 10 to 20 cm in length. Upon reaching maturity, the woody follicle splits longitudinally along a single suture to release numerous seeds. The seeds are small, measuring 3 to 7 mm in length, oblong to reniform in shape, light brown to dark brown, and densely covered with fine silky hairs. Each seed terminates in a tuft of long, plume-like hairs termed a pappus, facilitating anemochorous (wind-assisted) dispersal [22]. The root system consists of a robust, highly branched taproot accompanied by extensively spreading lateral roots that anchor the plant securely in rocky or loose alluvial soils [23].

Table 1. Taxonomical Classification of *Nerium oleander* L.

Kingdom	Plantae
Subkingdom	Tracheobionta (Vascular plants)
Superdivision	Spermatophyta (Seed plants)
Division	Magnoliophyta (Flowering plants)
Class	Magnoliopsida (Dicotyledons)
Subclass	Asteridae
Order	Gentianales
Family	Apocynaceae (Dogbane family)
Genus	*Nerium* L.
Species	*Nerium oleander* L.

2.2. Microscopic and Histological Characteristics

Histological examination of the leaf lamina reveals a dorsiventral anatomy tailored to minimize evapotranspiration [24]. The adaxial epidermis consists of a single layer of thick-walled, polygonal epidermal cells covered by a thick, continuous, smooth cuticular layer. Beneath the adaxial epidermis lies a multi-layered palisade mesophyll comprising two to three layers of tightly packed, elongated columnar cells rich in chloroplasts [25]. The spongy mesophyll occupies the central tissue region, consisting of loosely arranged, isodiametric parenchyma cells with moderate intercellular spaces.

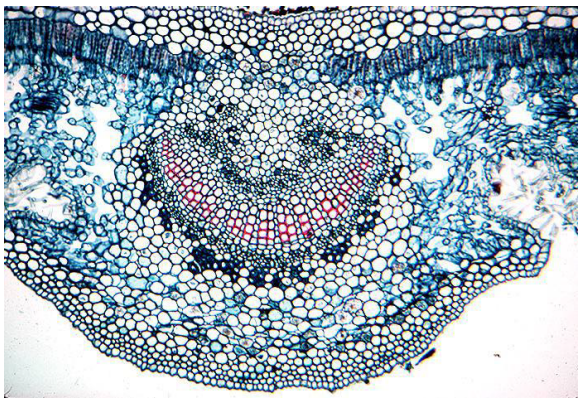

Figure 2. Cross section of mid rib of *Nerium oleander* L. (Source: Clayton, Michael W.)

An important microscopic feature of *Nerium oleander* is the presence of specialized abaxial stomatal crypts, also known as stomatal cavities or invaginations [26]. The abaxial epidermis forms deep depressions lined with non-glandular, unicellular, thick-walled, unbranched protective trichomes. The anomocytic stomata are confined exclusively within these crypts, isolated from direct atmospheric air currents to limit transpiration. Calcium oxalate crystals, predominantly in the form of solitary prisms and cluster crystals (druses), are distributed throughout the parenchymatous tissues of the leaf and stem cortex [27]. Non-articulated laticifer tubes are present alongside the phloem elements in vascular bundles, secreting latex rich in glycosides and enzymatic proteins [28].

3. Cultivation

3.1. Climate and Soil

Nerium oleander is native to the Mediterranean Basin, North Africa, and warm temperate to subtropical regions of Southwest Asia [29]. It exhibits exceptional ecological plasticity, enabling survival under extreme environmental conditions. Optimal growth occurs in Mediterranean, subtropical, and warm temperate climates characterized by hot, dry summers and mild winters [30]. The plant tolerates temperature fluctuations from high summer heat exceeding 40°C to brief frost exposures as low as -5°C to -10°C, though prolonged freezing conditions induce severe foliar necrosis and dieback [31].

The species is adapted to a wide array of soil textures, including coarse sandy soils, gravelly substrates, clay loams, and alluvial soils. It thrives in well-drained media across a pH spectrum ranging from 6.0 to 8.0, demonstrating tolerance to both moderately acidic and alkaline soils [32]. *Nerium oleander* possesses high halophytic tolerance, enduring elevated soil salinity and coastal salt spray without significant physiological impairment, making it an effective choice for soil stabilization and highway plantings [33].

3.2. Propagation

Full solar radiation exposure, requiring a minimum of 6 to 8 hours of direct daily sunlight, is necessary for abundant floral development and vigorous stem growth; plants grown in deep shade exhibit leggy vegetative stems with suppressed flowering [34]. Although established specimens demonstrate marked xerophytic drought resistance due to extensive root systems and protective foliar cuticle layers, regular irrigation during initial growth phases accelerates establishment and enhances blooming performance [35].

Propagation is primarily performed through vegetative methods to ensure clonal fidelity. Semi-hardwood or hardwood stem cuttings measuring 10 to 15 cm in length, taken during late spring or summer, readily form adventitious roots when placed in a moist substrate or water [36]. Seed propagation is less common for ornamental cultivars due to genetic segregation, though viable seeds germinate readily within 14 to 21 days under warm, humid conditions [37]. Pruning is recommended immediately following the primary flowering phase to maintain shrub architecture, stimulate branching, and remove spent inflorescences. Pest management requires routine monitoring for *Aphis nerii* (oleander aphid), scale insects (*Saissetia oleae*), and spider mites, alongside bacterial gall disease caused by *Pseudomonas savastanoi* pv. *nerii* [38].

4. Phytochemical Composition

4.1. Cardiac Glycosides and Cardenolides

The pharmacological and toxicological profile of *Nerium oleander* is dictated by a complex array of cardiac glycosides, specifically classified structurally as cardenolides [39]. Cardenolides consist of a steroid nucleus (C23 aglycone core) attached to an unsaturated five-membered γ-lactone ring at the C17 β position, combined with specific sugar moieties attached at the C3 hydroxyl group [40].

The major cardiac glycoside present throughout all organs is oleandrin ($C_{32}H_{48}O_9$), which yields the aglycone oleandrigenin upon enzymatic or acid hydrolysis [41]. Other identified cardenolides include digitoxigenin, folinerin, adynerin, neriin, rosagenin, kaneroside, neriumoside, gentiobiosyl-oleandrin, adigoside, and various odoroside isomers including odoroside A, odoroside B, and odoroside H [42]. Further phytochemical isolation has identified specific cardenolide monodesmosides and bisdesmosides, such as neridiginoside, nerizoside, neritaloside, and oleandigoside [43]. Cardenolide concentrations vary across anatomical tissues, with the highest levels recorded in seeds and mature leaves, followed by flowers, roots, and stems.

Table 2. Bioactive Phytoconstituent Classes and Representative Compounds in *Nerium oleander* L.

Chemical Class	Phytoconstituents	Plant Organs
Cardiac Glycosides (Cardenolides)	Oleandrin, digitoxigenin, folinerin, adynerin, neriin, odoroside A/B/H, neritaloside, nerizoside	Leaves, seeds, flowers, roots, bark
Pentacyclic Triterpenes	Ursolic acid, oleanolic acid, betulinic acid, betulin, *cis*-karenin, *trans*-karenin	Leaves, stems
Flavonoids & Polyphenols	Quercetin-3-*O*-rutinoside, kaempferol-3-*O*-rutinoside, chlorogenic acid, caffeic acid, ferulic acid	Leaves, flowers, roots
Volatile Monoterpenes & Sesquiterpenes	α-Pinene, β-Pinene, limonene, 1,8-cineole, β-phellandrene, sabinene, humulene	Flowers, fresh leaves

4.2. Triterpenoids, Steroids, and Fatty Acids

In addition to cardenolides, *Nerium oleander* synthesizes significant concentrations of pentacyclic triterpenoids, predominantly belonging to the ursane and oleanane structural families [44]. Key pentacyclic triterpene acids isolated from foliar tissues include ursolic acid, oleanolic acid, and betulinic acid, alongside the neutral triterpene alcohol betulin [45]. Research has identified specialized coumaryloxy pentacyclic triterpenes, notably cis-karenin (3β-hydroxy-28-Z-p-coumaroyloxy-urs-12-en-27-oic acid) and trans-karenin (3β-hydroxy-28-E-p-coumaroyloxy-urs-12-en-27-oic acid), together with nericoumaric acid and isonericoumaric acid [46]. Steroidal constituents identified in root and stem tissues include heptacosane derivatives, sterol glucosides, and various phytosterols [47]. Lipid analysis of seed oils and lipophilic tissue extracts reveals a fatty acid spectrum dominated by saturated and unsaturated species, including palmitic acid, stearic acid, oleic acid, linoleic acid, lauric acid, myristic acid, and arachidic acid [48].

4.3. Flavonoids, Phenolics, and Volatile Constituents

Flavonoid glycosides constitute a major portion of the hydrophilic phytochemical fraction in leaves and flowers [49]. The principal flavonoids include quercetin and kaempferol derivatives, specifically quercetin-3-O-rutinoside (rutin), kaempferol-3-O-rutinoside,

quercetin-5-O-[α-L-rhamnopyranosyl-(1 → 6)]-β-D-glucopyranoside, and kaempferol-5-O-[α-L-rhamnopyranosyl-(1 → 6)]-β-D-glucopyranoside [50]. Associated phenolic acids include chlorogenic acid, caffeic acid, gallic acid, ferulic acid, and p-coumaric acid, which contribute substantially to the antioxidant capacity of polar extracts [51].

Hydrodistillation of fresh flowers and leaves yields volatile essential oils rich in monoterpenes, sesquiterpenes, and aliphatic compounds [52]. Dominant volatile components identified via gas chromatography-mass spectrometry (GC-MS) include α -pinene, β-pinene, limonene, 1,8-cineole (eucalyptol), β-phellandrene, sabinene, 3-carene, humulene, p-cymen-8-ol, and 5-hydroxymethylfurfural [53].

5. Mechanisms of Toxicity and Safety

5.1. Molecular Mechanism of Na^+/K^+-ATPase Inhibition

The extreme toxicity of *Nerium oleander* is governed by the high-affinity binding of its principal cardenolides, oleandrin and digitoxigenin, to the extracellular domain of the α-subunit of the membrane-bound sodium-potassium adenosine triphosphatase (Na^+/K^+-ATPase) enzyme complex [54]. Under normal physiological conditions, Na^+/K^+-ATPase maintains resting membrane potential and intracellular ionic gradients by pumping three Na^+ ions out of the cytosol and two K^+ ions into the cell per hydrolytic cleavage of ATP [55].

When cardenolides bind to Na^+/K^+-ATPase, enzyme conformational changes inhibit ATP hydrolysis and transport activity, causing accumulation of intracellular sodium ions ($[Na^+]_i$) and reduction of intracellular potassium ions ($[K^+]_i$) [56]. The rise in intracellular sodium concentration impairs the thermodynamic driving force of the sarcolemmal sodium-calcium exchanger (Na^+/Ca^{2+} exchanger, NCX), reducing calcium efflux and driving reverse-mode NCX operation [57]. Consequently, cytosolic calcium ions ($[Ca^{2+}]_i$) accumulate rapidly, leading to increased calcium sequestration within the sarcoplasmic reticulum. Upon cardiac depolarization, enhanced sarcoplasmic calcium release triggers augmented cardiac myocyte contractility (positive inotropic effect) [58]. However, progressive calcium overload disrupts electrical cardiac conductance, triggers delayed afterdepolarizations, causes severe hyperkalemia, and culminates in dangerous ventricular arrhythmias [59].

$$\text{Cardenolide} + Na^+/K^+\text{-ATPase} \longrightarrow \text{Enzyme Inhibition} \longrightarrow\uparrow [Na^+]_i \longrightarrow \text{NCX Suppression} \longrightarrow\uparrow [Ca^{2+}]_i \longrightarrow \text{Arrhythmia}$$

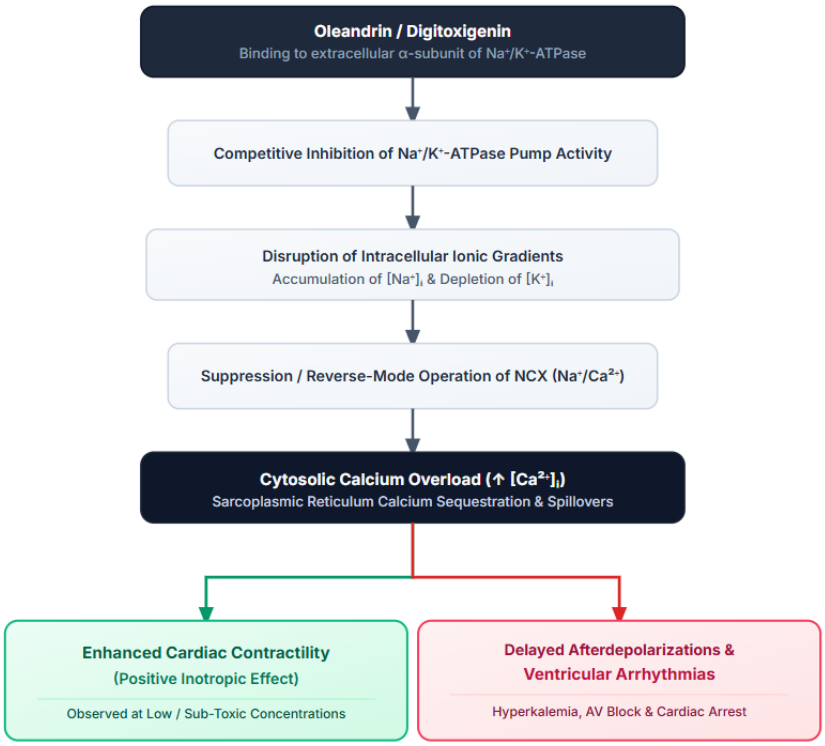

Figure 3. Cascade of Cardenolide-Induced Na^+/K^+-ATPase Inhibition and Calcium Overload

5.2. Clinical Manifestations and Management of Poisoning

Ingestion of any portion of *Nerium oleander*—whether fresh, dried, or cooked—induces acute systemic poisoning in humans and domestic animals [60]. Foliar lethal doses in livestock are estimated at 0.005% to 0.015% of body weight, making as few as 5 to 15 leaves fatal for adult cattle or horses [61].

Clinical symptoms manifest within 1 to 4 hours post-ingestion, involving gastrointestinal, cardiovascular, and neurological systems [62]. Gastrointestinal effects include severe nausea, emesis, abdominal pain, hyper-salivation, and tenesmus with bloody diarrhea. Cardiovascular signs present initially as sinus bradycardia, atrioventricular (AV) nodal block, and premature ventricular contractions (PVCs), escalating to ventricular tachycardia, ventricular fibrillation, and cardiac arrest [63]. Central nervous system disturbances involve lethargy, confusion, ataxia, mydriasis, visual aberrations, seizures, and coma. Severe acute hyperkalemia serves as a biomarker of profound Na^+/K^+-ATPase inhibition and directly correlates with clinical mortality [64].

Medical management of oleander poisoning requires immediate gastrointestinal decontamination via activated charcoal administration, continuous electrocardiographic monitoring, and aggressivecorrection of serum electrolyte imbalances [65]. Hyperkalemia must be controlled, while hypercalcemia should be avoided to prevent worsening calcium-induced arrhythmias. Digoxin-specific Fab antibody fragments (DigiFab) exhibit structural cross-reactivity with oleandrin and represent the definitive life-saving antidote for severe cardiac instability [66].

6. Pharmacological Activities

6.1. Cytotoxic and Antineoplastic Activity

Extensive preclinical investigations demonstrate significant antineoplastic activity of *Nerium oleander* extracts and purified cardenolides against diverse malignant cell lines [67]. Oleandrin exhibits selective cytotoxicity toward human tumor cells compared to non-malignant cells, operating through multiple molecular cascades including induction of apoptosis, arrest of the cell cycle at the G2/M phase, down-regulation of nuclear factor kappa B (NF-ϰB), and inhibition of the Akt/mTOR signaling pathway [68].

Oleandrin induces reactive oxygen species (ROS)-mediated mitochondrial membrane depolarization, triggering cytochrome c release into the cytosol and activating caspase-9 and caspase-3 enzymatic cascades [69]. Standardized extracts (such as PBI-05204, a supercritical carbon dioxide extract of *Nerium oleander*) enhance radiosensitivity and potentiate the cytotoxic efficacy of conventional chemotherapeutic agents like gemcitabine, cisplatin, and paclitaxel in pancreatic, non-small cell lung, and glioblastoma models [70].

6.2. Antimicrobial, Antifungal, and Antiparasitic Efficacy

Crude organic extracts derived from *Nerium oleander* leaves, flowers, and roots display broad-spectrum antimicrobial activity against pathogenic Gram-positive and Gram-negative bacteria [71]. Methanolic and ethanolic extracts inhibit *Staphylococcus aureus*, *Bacillus subtilis*, *Streptococcus pneumoniae*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* in agar diffusion assays [72].

Antifungal screening shows inhibitory effects against dermatophytic and opportunistic fungi, including *Candida albicans*, *Aspergillus niger*, *Microsporum canis*, and *Trichophyton rubrum* [73]. These antimicrobial effects are attributed to membrane-disrupting triterpenic acids, polyphenols, and bioactive flavonoids. Additionally, crude extracts exhibit antiparasitic and larvicidal activities against vectors such as *Anopheles stephensi* and *Aedes aegypti* larvae [74].

6.3. Anti-inflammatory, Analgesic, and Antioxidant Properties

Ethanolic and aqueous foliar extracts demonstrate notable anti-inflammatory and antinociceptive responses in animal models [75]. In carrageenan-induced paw edema assays, administration of standardized extracts significantly reduces acute inflammatory exudation and tissue edema [76]. The mechanism involves suppression of pro-inflammatory cytokines, including tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6), alongside inhibition of cyclooxygenase-2 (COX-2) expression and nitric oxide (NO) generation by inducible nitric oxide synthase (iNOS) [77].

Antioxidant assays, including DPPH radical scavenging, ABTS cation decolorization, and ferric reducing antioxidant power (FRAP) evaluations, confirm strong radical-neutralizing capacity [78]. High total phenolic and flavonoid contents correlate directly with inhibition of lipid peroxidation and protection against oxidative cellular damage [79].

Table 3. Pharmacological Activities of *Nerium oleander* Extracts and Constituents

Pharmacological Activities	Bioactive Constituents	Mechanism of Action / Experimental Model
Antineoplastic / Cytotoxic	Oleandrin, PBI-05204 extract, digitoxigenin	Caspase activation, ROS generation, NF-κB inhibition, G_2/M cell cycle arrest
Antimicrobial / Antifungal	Flavonoids, polyphenols, triterpene acids	Bacterial membrane permeability alteration, fungal spore germination inhibition
Anti-inflammatory / Analgesic	Ursolic acid, oleanolic acid, quercetin derivatives	COX-2 inhibition, reduction of TNF-α, IL-1β, and iNOS-derived nitric oxide
Antioxidant	Chlorogenic acid, rutin, kaempferol glycosides	Free radical scavenging (DPPH, ABTS), prevention of lipid peroxidation

7. Traditional Uses and Ethnomedicinal History

Across historical ethnomedicinal systems, *Nerium oleander* occupied a specialized role as a potent topical therapeutic [80]. In Ayurvedic medicine, *Karaveera* root bark and foliar pastes were formulated in oil bases for external application to manage chronic dermatological conditions, eczema, scabies, ringworm, leprosy lesions, and infected cutaneous wounds [81]. The potent antimicrobial and counter-irritant properties of the plant provided clinical rationale for these localized therapies.

In traditional Mediterranean and Middle Eastern herbal medicine, diluted leaf decoctions were used as scalp washes to treat pediculosis and seborrheic dermatitis, or as localized poultices to alleviate joint pain and inflammatory swellings [82]. However, ancient texts explicitly warned against internal consumption without rigorous processing, recognizing the severe risk of fatal cardiovascular toxicity [83]. Contemporary pharmacognostic standards reinforce that systemic oral administration of unstandardized crude oleander preparations presents severe safety risks and should be avoided [84].

8. Conclusion

Nerium oleander L. contains diverse secondary metabolites with significant pharmacological activity alongside high acute toxicity. The structural characterization of its cardenolides, particularly oleandrin and digitoxigenin, sheds light into its targeted inhibition of Na^+/K^+-ATPase, which drives both its positive inotropic potential and its dangerous cardiotoxic effects. The accumulation of pentacyclic triterpenes, polyphenols, and flavonoids underpins its marked cytotoxic, anti-inflammatory, antimicrobial, and antioxidant properties. Modern biomedical research into purified constituents and standardized extracts highlights the therapeutic potential of this plant while systemic ethnomedicinal utilization remains constrained by a narrow therapeutic window. Modern analytical techniques will further clarify the therapeutic utility of these chemical constituents while improving clinical management of cardenolide poisoning.

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