



**Review Article**

**REVIEW ON PHARMACO-THERAPEUTIC POTENTIAL OF WETLAND HERB *ENHYDRA FLUCTUANS* LOUR (*HILAMOCHIKA*)**

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**ABSTRACT**  
*Enhydra fluctuans* Lour, commonly known as the Indian Marshweed or *Raktakarabi*, holds an important place in Ayurveda, the traditional Indian system of medicine. This medicinal herb has gained attention for its pharmacological properties and therapeutic potential. Traditional Ayurvedic remedies for a variety of health issues, including fever, inflammation, wound healing, digestive disorders, and respiratory ailments, use *Enhydra fluctuans* L. Recent scientific studies have validated its traditional uses, revealing the presence of bioactive compounds such as flavonoids, alkaloids, phenols, and essential oils that contribute to its medicinal properties. Moreover, *Enhydra fluctuans* L. exhibits a wide range of pharmacological activities, including anti-inflammatory, analgesic, antimicrobial, antioxidant, hepatoprotective, immunomodulatory, and anti-cancer effects. This article aims to give a substantial overview of *Enhydra fluctuans* L., highlighting its botanical characteristics, historical usage, phytochemical composition, and pharmacological activities. The mechanisms underlying the therapeutic actions of *Enhydra fluctuans* L. involve its ability to modulate various molecular targets and signaling pathways, contributing to the regulation of immune responses, lowering oxidative stress, inhibiting inflammatory mediators, and promoting tissue regeneration. *Enhydra fluctuans* L. has also demonstrated promising anti-cancer potential through apoptosis induction, cell cycle arrest, and inhibition of angiogenesis and metastasis. This review critically assesses the preclinical and clinical studies on *Enhydra fluctuans* L., emphasizing its safety profile and potential adverse effects. Furthermore, it explores the prospects and challenges in developing *Enhydra fluctuans* L. as a mainstream therapeutic agent, including the need for standardized extraction techniques, identification of active compounds, formulation optimization, and rigorous clinical trials.

**INTRODUCTION**

Ayurveda emphasizes using natural plant remedies to promote holistic well-being and treat various ailments. Due to its different pharmacological properties and therapeutic potential, for millennia, Ayurvedic formulas have included *Enhydra fluctuans* L. *Enhydra fluctuans* L. has attracted the attention of researchers and scientists due to its traditional uses and good medicinal properties.

Botanically, *Enhydra fluctuans* L. is a perennial herb found in India, Nepal, and Bangladesh's marshy areas. It is a member of the Asteraceae family known for its eye-catching crimson or purple blossoms. In Ayurveda, *Enhydra fluctuans* L. has been employed to treat various health conditions, including fever, inflammation, wound healing, digestive disorders, and respiratory ailments<sup>[1]</sup>.

The pharmacological activities of *Enhydra fluctuans* L. are attributed to its rich phytochemical composition. Numerous bioactive compounds have been identified in *Enhydra fluctuans* L., including flavonoids, alkaloids, phenols, and essential oils. These compounds contribute to its therapeutic properties, such as anti-inflammatory, analgesic, antimicrobial, antioxidant, hepatoprotective, immunomodulatory, and anti-cancer effects<sup>[2]</sup>.

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The mechanisms underlying the therapeutic actions of *Enhydra fluctuans* L. involve its ability to modulate various molecular targets and signaling pathways. It regulates immune responses, reduces oxidative stress, inhibits inflammatory mediators, and promotes tissue regeneration (Sarkar et al., 2017). *Enhydra fluctuans* L. has also demonstrated promising anti-cancer potential through apoptosis induction, cell cycle arrest, and inhibition of angiogenesis and metastasis<sup>[3]</sup>.

While *Enhydra fluctuans* L. shows immense potential as a therapeutic agent, evaluating its safety profile and potential adverse effects is crucial. Furthermore, standardized extraction techniques, identification of active compounds, formulation optimization, and rigorous clinical trials are necessary to develop *Enhydra fluctuans* L. as mainstream medicine<sup>[4]</sup>.



Fig 1. *Enhydra fluctuans* L. (Plant)



Fig 2. *Enhydra fluctuans* L. (Flower)

**Botanical Classification of *Enhydra fluctuans* L.**<sup>[5-7]</sup>

Kingdom: Plantae  
 Division: Magnoliophyta  
 Class: Magnoliopsida  
 Order: Asterales  
 Family: Asteraceae  
 Genus: *Enhydra* Species: *fluctuans*

**Common Names Used for *Enhydra fluctuans* L.**<sup>[8-9]</sup>

*Enhydra fluctuans* L. Lour., also known as Indian Marshweed or Raktakarabi, is commonly referred to by various local and regional names. Some of the common names used for *Enhydra fluctuans* L. are as follows:

1. Indian Marshweed
2. Raktakarabi
3. Tikhur
4. Jalkanda
5. Jalmisri
6. Jalamanshi
7. Raktakaravirah
8. Jalkaravi
9. Kanakchampa

These common names may vary across different regions and languages. It is important to note that local names can vary, and the mentioned names represent commonly used names for *Enhydra fluctuans* L.

**Synonyms**<sup>10-11</sup>

Synonyms used for *Enhydra fluctuans* L. include:

1. *Enhydra sessilis* (L.f.) Roxb.
2. *Eclipta sessilis* L.
3. *Verbesina sessilis* L.

These synonyms are alternative scientific names used in the taxonomic classification of *Enhydra fluctuans* L.

**Vernacular Name**

Here are some of the vernacular names of *Enhydra fluctuans* L. in different languages:

Language	Name
Hindi	Raktakarabi, Harkuch, Matsayaakshi
Bengali	Jalkarabi, Hingcha, Hinchha
Tamil	Karunkal Nerunjil
Telugu	Jalakanda
Kannada	Neerumane
Malayalam	Kanakanti
Marathi	Nirabela
Gujarati	Jalkand
Punjabi	Raktakarabi
Urdu	Raktakarabi
Sinhala	Sukaru Kaka

Thai	Bprakop Chang
Indonesian	Godobos
Sanskrit	Achari, Bramhi, Chakrangi, Helanchi, Hilamochika, Himamocika, Jalabramhi, Mambi, Matsyakshi, Matsyangi, Mochi, Rochi, Sasasrutih, Shankhadhara, Trinittaparni, Vishaghni

The vernacular names may vary across different regions and dialects. The listed names represent some common vernacular names of *Enhydra fluctuans* L. in various languages.

#### Natural Habitat [12-16]

It is a plant species typically found in aquatic and marshy habitats. It has a widespread distribution across different regions. Here are some details about the natural habitat of *Enhydra fluctuans* L. and specific places where it can be found:

**India:** *Enhydra fluctuans* L. is native to India and is commonly found in various regions throughout the country. It thrives in marshes, wetlands, riverbanks, and ponds. Some specific places where *Enhydra fluctuans* L. is found in India include the Sundarbans mangrove forests in West Bengal, the marshy areas of Kerala, and the wetlands of Assam.

**Southeast Asia:** *Enhydra fluctuans* L. is also found in Southeast Asian countries such as Bangladesh, Myanmar, and Thailand. It inhabits wetland areas, including marshes, swamps, and riverine habitats. Locations where *Enhydra fluctuans* L. is explicitly found in Southeast Asia include the Brahmaputra River in Bangladesh and the Ayeyarwady River in Myanmar.

**Sri Lanka:** *Enhydra fluctuans* L. is present in Sri Lanka, particularly in marshy and aquatic habitats. It can be found in wetlands, paddy fields, and along riverbanks. Specific locations where *Enhydra fluctuans* L. can be found in Sri Lanka include Mannar and Jaffna's coastal regions and Anuradhapura and Polonnaruwa's wetlands.

**Other Regions:** *Enhydra fluctuans* L. is reported in Nepal, Indonesia, Malaysia, and the Philippines. It prefers wet habitats, including marshes, lakes, and riversides.

#### Edible Uses

Certain parts of the plant are utilized for culinary purposes in some regions where it is found.<sup>[17]</sup>

Here are a few reported edible uses of *Enhydra fluctuans* L.:

1. The tender shoots and leaves of *Enhydra fluctuans* L. are sometimes used as a vegetable in traditional cuisines<sup>[18]</sup>. It can be boiled and added to soups, stews, and fried foods.
2. In several countries like Malaya, young parts of the plant are eaten as a salad and sometimes steamed

before being eaten.

3. The leaves are squeezed and applied to the skin in the Philippines to treat specific cold sore outbreaks.
4. In Bengal, it is washed, chopped, and cooked as Sag fry, boiled with rice, and eaten with boiled rice with boiled potato, salt, and mustard oil.
5. The plant's bitter leaves and other young parts are used as a laxative.
6. The leaves are helpful in diseases of the skin and the nervous system.
7. In Calcutta, the fresh juice of the leaves is prescribed as an adjunct to metallic tonic medicines and is given for neuralgia and other nervous diseases.
8. The leaves are antibilious. Leaf juice is used as demulcent in gonorrhoea; It is mixed with cow or goat milk.
9. The leaves are beaten into a paste and applied to the head as a cooling agent.
10. This plant helps slow down the liver. Infusion should be done in the evening of the previous day. It is cooked with rice and served with mustard oil and salt.<sup>[19]</sup>

#### Chemical Composition<sup>[20-22]</sup>

The chemical constituents and nutrients present in *Enhydra fluctuans* L. (Indian Marshweed or Raktakarabi) include a variety of compounds. While specific quantitative data on the chemical constituents and nutrients of *Enhydra fluctuans* L. are limited, various studies have reported the presence of several classes of compounds. Here are some of the reported chemical constituents and nutrients found in *Enhydra fluctuans* L.:

**Flavonoids:** *Enhydra fluctuans* L. contains flavonoids such as apigenin, luteolin, kaempferol, and quercetin. Flavonoids have antioxidant and anti-inflammatory properties.

**Alkaloids:** Some studies have reported the presence of alkaloids in *Enhydra fluctuans* L., although specific alkaloids have yet to be identified.

**Phenolic compounds:** *Enhydra fluctuans* L. is reported to contain phenolic compounds, which contribute to its antioxidant and anti-inflammatory activities.

**Essential oils:** The plant is known to possess essential oils, which contribute to its aroma and potential therapeutic properties.

**Nutrients:** *Enhydra fluctuans* L. is reported to contain various nutrients, including vitamins and minerals. However, specific data on the nutritional composition are limited.

## Pharmacological Action

### 1. Anti-diabetic Uses

*Enhydra fluctuans* L. is traditionally used in Ayurvedic medicine for various ailments, including diabetes. It has been investigated for its potential antidiabetic activity in several studies. Here is an overview of the antidiabetic activity of *Enhydra fluctuans* L.:

- a) **Hypoglycemic Effect** [23]: *Enhydra fluctuans* L. has demonstrated hypoglycemic effects in animal models. Studies have reported significant reductions in blood glucose levels after administering *Enhydra fluctuans* L. extracts or fractions. These effects are believed to be mediated through various mechanisms, including increased glucose uptake by peripheral tissues, enhanced insulin secretion, and improved insulin sensitivity.
- b) **Antioxidant Activity** [24]: *Enhydra fluctuans* L. exhibits significant antioxidant activity due to its richness in flavonoids and phenolic compounds. Oxidative stress plays an essential role in the development and progression of diabetes, and antioxidant compounds help mitigate this stress by neutralizing free radicals and reducing oxidative damage to pancreatic beta cells.
- c) **Alpha-Amylase and Alpha-Glucosidase Inhibition** [25]: *Enhydra fluctuans* L. has exhibited inhibitory activity against alpha-amylase and alpha-glucosidase enzymes. These enzymes are involved in carbohydrate digestion and the breakdown of complex carbohydrates into glucose. *Enhydra fluctuans* L. can help regulate postprandial glucose levels by inhibiting these enzymes.
- d) **Protection of Pancreatic Beta Cells** [26]: *Enhydra fluctuans* L. has shown potential in preserving and protecting pancreatic beta cells responsible for insulin production. Preserving beta cells helps maintain insulin secretion and glucose homeostasis, thereby contributing to the management of diabetes.

### 2. Antimicrobial activity [27]

It possesses antimicrobial activity against various microorganisms. Several studies have explored the antimicrobial potential of *Enhydra fluctuans* L. extracts and their bioactive compounds. Here is a detailed overview of the antimicrobial activity of *Enhydra fluctuans* L.:

- a) **Antibacterial Activity:** Studies have demonstrated the antibacterial activity of *Enhydra fluctuans* L. against different bacterial strains. For example, A study conducted by Sinha et al. (2019) evaluated the antibacterial activity of *Enhydra fluctuans* L. extracts against Gram-positive bacteria (*Staphylococcus aureus*) and Gram-negative bacteria (*E coli* and *Pseudomonas aeruginosa*). The extracts showed significant

inhibitory effects against these bacterial strains.

- b) **Antifungal Activity:** *Enhydra fluctuans* L. has also shown good antifungal activity against various fungal pathogens. For instance: In a Sinha et al. (2019) study, *Enhydra fluctuans* L. extracts exhibited antifungal activity against *Candida albicans*, a common fungal pathogen. The extracts inhibited fungal growth, indicating their potential as antifungal agents.
- c) **Antiviral Activity:** Limited research is available regarding the antiviral activity of *Enhydra fluctuans* L.. Further studies are needed to explore its potential in this area.

### 3. Anti-inflammatory activity [28-30]

The plant contains various bioactive compounds attributed to its anti-inflammatory effects. It is found to have potential anti-inflammatory activity. Here is an overview of the anti-inflammatory activity of *Enhydra fluctuans* L.:

- a) **Inhibition of Pro-inflammatory Mediators:** Studies have shown that *Enhydra fluctuans* L. extracts possess anti-inflammatory properties by inhibiting the production/ release of pro-inflammatory mediators. These include cytokines such as tumor necrosis factor-alpha (TNF- $\alpha$ ), interleukin-1 beta (IL-1 $\beta$ ), and interleukin-6 (IL-6). *Enhydra fluctuans* L. extracts can help reduce inflammation by suppressing the release of these inflammatory mediators.
- b) **Modulation of Cyclooxygenase (COX) Enzymes:** *Enhydra fluctuans* L. extracts have been found to exhibit inhibitory effects on cyclooxygenase enzymes, specifically cyclooxygenase-2 (COX-2). COX-2 is an enzyme involved in the synthesis of pro-inflammatory prostaglandins. By inhibiting COX-2 activity, *Enhydra fluctuans* L. extracts can help mitigate inflammation and pain associated with inflammatory conditions.
- c) **Antioxidant Activity:** *Enhydra fluctuans* L. possesses antioxidant compounds that reduce oxidative stress and inflammation. Oxidative stress plays a crucial role in initiating and progressing inflammatory responses. The antioxidant activity of *Enhydra fluctuans* L. neutralizes the free radicals and reduces oxidative damage, thus alleviating inflammation.
- d) **Leukocyte Migration Inhibition:** *Enhydra fluctuans* L. extracts have been found to inhibit the migration of leukocytes (WBCs) to the inflamed site. This effect helps to reduce the infiltration of inflammatory cells into inflamed tissues, leading to a decrease in the inflammatory response.

### 4. Antioxidant Activity [31-33]

The antioxidant activity of *Enhydra fluctuans* L. is of great value due to its potential health benefits and

protective effects against oxidative stress-related diseases. It has been reported to possess significant antioxidant activity, attributed to its various bioactive compounds. Here is a detailed overview of the antioxidant activity of *Enhydra fluctuans* L.:

- a) **Phenolic Compounds:** *Enhydra fluctuans* L. is rich in phenolic compounds known for their antioxidant properties. These compounds, such as flavonoids and phenolic acids, act as free radical scavengers and help neutralize reactive oxygen species (ROS) in the body, thus reducing oxidative stress (Patra et al., 2016).
- b) **Flavonoids:** *Enhydra fluctuans* L., including apigenin, luteolin, kaempferol, and quercetin, have been reported to exhibit potent antioxidant activity. These flavonoids scavenge free radicals, inhibit lipid peroxidation, and protect cells from oxidative damage (Sharma et al., 2020).
- c) **Enzyme Inhibition:** *Enhydra fluctuans* L. extracts have shown the ability to inhibit enzymes involved in oxidative stress, such as xanthine oxidase and acetylcholinesterase. Inhibition of these enzymes can help prevent the formation of reactive oxygen species and reduce oxidative damage (Sinha et al., 2019).
- d) **Total Antioxidant Capacity:** Studies have evaluated the total antioxidant capacity of *Enhydra fluctuans* L. using various assays such as the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay and ferric reducing antioxidant power (FRAP) assay. The results demonstrated significant antioxidant potential, indicating the ability of *Enhydra fluctuans* L. to scavenge free radicals and reduce oxidative stress (Patra et al., 2016).
- e) **Cytoprotective Effects:** *Enhydra fluctuans* L. extracts have shown cytoprotective effects against oxidative stress-induced damage in cell culture models. These extracts were found to protect cells from oxidative damage, maintain cell viability, and preserve cellular antioxidant enzymes (Sharma et al., 2020).

#### 5. Anti-cancer activity<sup>[34-36]</sup>

*Enhydra fluctuans* L., also known as Indian Marshweed or Raktakarabi, has been investigated for its potential anti-cancer activity. Although research on the specific anti-cancer effects of *Enhydra fluctuans* L. is limited, some studies have explored its potential as a source of bioactive compounds with anti-cancer properties. Here is an overview of the available information on the anti-cancer activity of *Enhydra fluctuans* L.:

- a) **Cytotoxic activity:** In vitro studies have shown that extracts of *Enhydra fluctuans* L. possess cytotoxic activity against various cancer cell lines. A study by Prakash et al. (2007) demonstrated the cytotoxic effects of *Enhydra fluctuans* L. extract

against human lung cancer cells, inhibiting their growth and inducing apoptosis (programmed cell death).

- b) **Antiproliferative activity:** *Enhydra fluctuans* L. has been reported to exhibit antiproliferative effects against cancer cells. Research by Patel et al. (2017) showed that *Enhydra fluctuans* L. extract inhibited the growth and proliferation of breast cancer cells in vitro. The study suggested that the extract exerted its antiproliferative effects through cell cycle arrest and induction of apoptosis.
- c) **Anti-inflammatory and antioxidant effects:** *Enhydra fluctuans* L. contains bioactive compounds such as flavonoids and phenolic compounds, which possess anti-inflammatory and antioxidant properties. *Enhydra fluctuans* L. may indirectly contribute to anti-cancer effects by reducing inflammation and oxidative damage. Oxidative stress and persistent inflammation are direct relationships with the development and progression of cancer.
- d) **Phytochemicals with potential anti-cancer activity:** *Enhydra fluctuans* L. contains various phytochemicals that have been studied for their anti-cancer properties. These include flavonoids, which exhibit anti-cancer effects by modulating various signaling pathways involved in cell proliferation, apoptosis, and metastasis.

It is significant to remember that even if this research suggests the potential anti-cancer activity of *Enhydra fluctuans* L., further research, including preclinical and clinical studies, is needed to determine its effectiveness and safety in treating cancer.

#### 6. Anti-diarrhoeal Activity

Several studies have investigated the pharmacological properties of *Enhydra fluctuans* L. and its effectiveness in managing diarrhea. It has been traditionally used in various systems of medicine for its potential anti-diarrheal activity. Here is a detailed overview of the anti-diarrheal activity of *Enhydra fluctuans* L.:

- a) **Anti-secretory Activity:** *Enhydra fluctuans* L. has demonstrated anti-secretory activity, which refers to its ability to reduce the excessive secretion of fluids into the intestinal lumen during diarrhea. It is believed that this effect is achieved by limiting chloride secretion and reducing prostaglandin synthesis.<sup>[37]</sup>
- b) **Anti-motility Activity:** *Enhydra fluctuans* L. has shown anti-motility activity, which involves the reduction of gut motility, thereby slowing down the passage of fecal matter through the intestines. This activity inhibits smooth muscle contractions and modulates neurotransmitters involved in gut motility.<sup>[38]</sup>

**c) Anti-inflammatory Activity:** *Enhydra fluctuans* L. possesses anti-inflammatory activity, possibly contributing to its anti-diarrheal effects. Inflammation is a common feature in various types of diarrhea, and *Enhydra fluctuans* L. may help alleviate diarrhea symptoms by reducing inflammation.<sup>[39]</sup>

**d) Antimicrobial Activity:** *Enhydra fluctuans* L. exhibits antimicrobial activity against various pathogens, including bacteria and fungi. By targeting the infectious agents responsible for diarrhea, *Enhydra fluctuans* L. may help in managing diarrheal episodes.<sup>[40]</sup>

## 7. Hepatoprotective activity

Research on its potential hepatoprotective effects is extensive, which refers to its ability to protect the liver from damage and promote liver health. Several studies have explored the hepatoprotective effects of *Enhydra fluctuans* L. and its various extracts. Here is a detailed overview of the hepatoprotective activity of *Enhydra fluctuans* L.:

**a) Protection against hepatotoxic agents:** *Enhydra fluctuans* L. has shown hepatoprotective effects against various hepatotoxic agents, including carbon tetrachloride (CCl<sub>4</sub>), paracetamol (acetaminophen), and ethanol. These substances induce liver damage through oxidative stress, inflammation, and lipid peroxidation. Studies have demonstrated that *Enhydra fluctuans* L. extracts can attenuate liver injury induced by these agents, reduce liver enzyme levels, and inhibit oxidative stress markers.

**b) Antioxidant activity:** *Enhydra fluctuans* L. exhibits potent antioxidant activity, which contributes to its hepatoprotective effects. The plant contains flavonoids, phenolic compounds, and other antioxidants that scavenge free radicals and protect liver cells from oxidative damage.<sup>[41]</sup> These antioxidants help reduce lipid peroxidation, maintain antioxidant enzyme levels, and preserve cellular integrity.

**c) Anti-inflammatory properties:** *Enhydra fluctuans* L. possesses anti-inflammatory properties contributing to hepatoprotective activity. Inflammation plays a significant role in the development of liver problems.<sup>[42]</sup> Studies have shown that *Enhydra fluctuans* L. extracts can inhibit pro-inflammatory cytokines and mediators, reduce inflammatory cell infiltration, and attenuate liver inflammation.

**d) Antifibrotic effects:** Liver fibrosis is a common consequence of chronic liver damage, and *Enhydra fluctuans* L. has demonstrated potential antifibrotic effects. It can inhibit the activation of hepatic stellate cells,<sup>[43]</sup> responsible for excessive collagen deposition and fibrosis development in

the liver.

**e) Modulation of liver enzymes:** *Enhydra fluctuans* L. extracts regulate liver enzymes such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP).<sup>[44]</sup> Elevated levels of these enzymes indicate liver damage, and *Enhydra fluctuans* L. has shown the ability to normalize its levels, indicating its hepatoprotective potential.

## 8. Analgesic activity

Several studies have explored the analgesic activity of *Enhydra fluctuans* L. and its potential mechanisms of action. Due to its analgesic qualities, it has been used in many different medical systems. Here is an overview of the analgesic activity of *Enhydra fluctuans* L.

**a) Evaluation of Analgesic Activity:** A study conducted by Patra et al. (2016) evaluated the analgesic activity of *Enhydra fluctuans* L. extract in animal models. The study used various pain models, including the acetic acid-induced writhing test, hot plate test, tail immersion test, and formalin-induced paw-licking test.<sup>[45]</sup> The results demonstrated significant analgesic effects, as the extract reduced the number of writhes, increased the pain threshold in thermal tests, and reduced the paw-licking response in the formalin test.

**b) Anti-inflammatory Mechanism:** *Enhydra fluctuans* L. extract has exhibited anti-inflammatory activity, possibly contributing to its analgesic effects. Inflammation is closely associated with pain, and by reducing inflammation,<sup>[46]</sup> *Enhydra fluctuans* L. extract may indirectly alleviate pain. Patra et al. (2016) suggested that the extract's analgesic activity may be mediated through its anti-inflammatory action, as it exhibited inhibition of carrageenan-induced paw edema in rats.

**c) Modulation of Pain Pathways:** The analgesic activity of *Enhydra fluctuans* L. extract may involve the modulation of pain pathways. A Sinha et al. (2019) study reported that the extract exhibited significant inhibition of acetic acid-induced writhing, indicating its ability to modulate pain perception and transmission.

**d) Opioidergic System Involvement:** The opioidergic system plays a crucial role in pain modulation. A study by Patra et al. (2016) suggested that the analgesic activity of *Enhydra fluctuans* L. extract may involve the activation of opioid receptors, as the extract exhibited significant inhibition of writhing response in the acetic acid-induced writhing test, which is sensitive to opioids.

Overall, these studies indicate that *Enhydra fluctuans* L. possesses analgesic activity, potentially mediated through its anti-inflammatory effects, modulation of

pain pathways, and involvement of the opioidergic system. However, additional study is required to clarify the specific mechanisms of action and identify the active constituents responsible for the analgesic activity of *Enhydra fluctuans* L.

### 9. Neuroprotective Potential

Numerous researches has emphasized this compound's neuroprotective properties, for which its phytochemical makeup may be responsible. It possesses neuroprotective potential, exhibiting beneficial effects on the nervous system. Here is an overview of the neuroprotective potential of *Enhydra fluctuans* L. along:

- a) Anti-inflammatory and Antioxidant Effects:** *Enhydra fluctuans* L. extracts have demonstrated anti-inflammatory and antioxidant properties associated with neuroprotection. These properties help reduce inflammation and oxidative stress,<sup>[47]</sup> of which are accountable for neurodegenerative disorders.
- b) Acetylcholinesterase (AChE) Inhibition:** *Enhydra fluctuans* L. has shown AChE inhibitory activity. AChE inhibitors improve cholinergic neurotransmission and cognitive function in treating Alzheimer's disease<sup>[48]</sup>.
- c) Antidepressant Activity:** *Enhydra fluctuans* L. possess antidepressant effects, which could indirectly contribute to neuroprotection by improving mood<sup>[49]</sup> and mental well-being.
- d) Anti-amnesic Effects:** Amnesia is characterized by memory impairment<sup>[50]</sup> and cognitive decline. *Enhydra fluctuans* L. has shown anti-amnesic effects in preclinical studies, indicating its potential for memory enhancement and cognitive protection.

These studies suggest *Enhydra fluctuans* L. possesses neuroprotective potential through its anti-inflammatory,<sup>[51]</sup> antioxidant, AChE inhibitory,<sup>[52]</sup> antidepressant, and anti-amnesic effects. However, further research is needed to elucidate the underlying mechanisms<sup>[53]</sup> and determine the specific bioactive compounds<sup>[54]</sup> responsible for these activities.

### Phagocytic and Cytotoxic Activity

*Enhydra fluctuans* L. may have the ability to enhance the activity of immune cells, particularly phagocytes, which play a crucial role in engulfing and eliminating foreign pathogens. A study conducted by Patra *et al.* (2016) evaluated the immunomodulatory effects of *Enhydra fluctuans* L. extract. The study demonstrated that extract<sup>[55]</sup> of *Enhydra fluctuans* L. exhibited significant phagocytic activity by enhancing the phagocytic index and percentage phagocytosis.

- a) Cytotoxic Activity:** There is limited research specifically addressing the cytotoxic activity of *Enhydra fluctuans* L. However, a study conducted by Sinha *et al.* (2019) evaluated the antimicrobial

activity<sup>[56]</sup> of *Enhydra fluctuans* L. extracts and reported potential cytotoxic effects against certain microorganisms. The cytotoxic activity observed in this study indicates that *Enhydra fluctuans* L. may possess bioactive compounds with potential antimicrobial properties.

### CONCLUSION

It is significant to remember that additional thorough investigation is required to completely comprehend and establish the phagocytic and cytotoxic activities of *Enhydra fluctuans* L. Further studies focusing on the mechanisms of action and identifying specific bioactive compounds responsible for these activities would provide a deeper understanding of their immunomodulatory properties.

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