



REVIEW ARTICLE

Endosulfan-Induced Toxicity: An Ayurvedic Perspective

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Abstract

Endosulfan, a persistent organochlorine pesticide, is globally recognized for its severe toxicological impact on both human health and the environment. Despite its ban under the Stockholm Convention in 2011, its residual presence continues to cause widespread harm to humans and ecosystems. Exposure to endosulfan occurs via multiple routes, including air, water, food, skin contact, and even maternal transmission, leading to a wide array of health consequences, such as neurotoxicity, hormone disruption, reproductive problems, hepatic and renal impairment, and developmental delays. This article examines endosulfan-induced toxicity through the lens of Ayurvedic toxicology, focusing on the concepts of *Garavisha*, *Dhooshivisha*, and *Janapadodhwamsa*. *Garavisha* refers to artificial toxins formed by the interaction of otherwise non-toxic substances, bearing a resemblance to the chemical nature and acute effects of endosulfan. *Dhooshivisha*, a latent or residual toxin that remains in the body over time, closely parallels the chronic bioaccumulative effects and persistent systemic toxicity of endosulfan. Furthermore, the significant ecological damage caused by aerial spraying and contamination of soil and water illustrates the Ayurvedic principle of *Janapadodhwamsa*, which refers to widespread health crises caused by disruptions in air (*vata*), water (*jala*), locality (*desa*), and time (*kala*). The convergence of these toxicological paradigms underscores the relevance of Ayurvedic insights in understanding and managing pesticide-induced disorders.

Introduction

Endosulfan, an organochlorine pesticide (OCP), is widely employed in large-scale agriculture to manage various insects and mites that infest both food and non-food crops.^[1] Once applied, the pesticide can drift from the target site to surrounding non-target areas, potentially impacting not only the intended pests but also non-target and endangered species.^[2] Endosulfan, similar to other organochlorine pesticides (OCPs), is known for its bioaccumulative nature, toxicity, and environmental persistence.^[1] Humans may be unintentionally exposed to it through various routes, including inhalation, ingestion of contaminated food, dermal contact, as well as through transplacental transfer and breastfeeding.^[1] It is recognized as an endocrine-disrupting chemical.^[1]

In April 2011, the Stockholm Convention called for a global ban on the production and use of endosulfan, citing its detrimental effects on human health and the environment.^[3] Numerous studies, reviews, and official reports consistently highlight that endosulfan can lead to fatal outcomes and severe acute and chronic toxicity affecting multiple organ systems.^[4] These include cognitive impairment, neurological disturbances, immune system suppression, reproductive and developmental toxicity, as well as damage to the liver, kidneys, heart, and blood.^[4] In India, particularly in regions such as Kerala and Karnataka, numerous studies have reported a significantly higher prevalence of intellectual and physical disabilities, various cancers, epilepsy, and developmental abnormalities among populations exposed to aerial spraying of endosulfan.^[5,6] A case-control study revealed endosulfan residues in the bone marrow of 23% of children diagnosed with leukemia, compared to only 4% among healthy controls, indicating a strong association with haematological malignancies (OR = 7.5).^[7]

In Ayurveda, poisons are categorized into several groups based on their origin, properties, and effects on the body. Among these *Garavisha* denotes an artificially compounded poison that arises from the combination of two or more non-poisonous substances while *Dhooshivisha* refers to a type of poison that, once it enters the body, stays latent and manifests as disease only after a certain period.^[8,9] Ayurveda recognises not only individual disorders but also collective afflictions affecting large groups of people. Such widespread occurrences are explained under the concept of *Janapadodhwamsa*, which denotes mass destruction or epidemics resulting from the disturbance of commonly shared environmental factors. According to the *Charaka Samhita*, the factors responsible for *Janapadodhwamsa*, leading to the vitiation of environmental elements, are *Vayu* (air), *Jala* (water), *Desha* (place), and *Kala* (climate or season). These imbalances collectively disrupt the ecological harmony and give rise to diseases that affect entire communities rather than individuals.

There is a notable research gap in understanding endosulfan-induced toxicity through Ayurvedic paradigms. This article addresses this gap by interpreting endosulfan toxicity in light of classical Ayurvedic concepts such as *Garavisha*, *Dhooshivisha*, and *Janapadodhwamsa*. By identifying parallels between these traditional concepts and the modern understanding of chronic chemical exposure, this study contributes to a broader perspective on the recognition and interpretation of such toxicities. Ayurveda offers well-defined therapeutic protocols for conditions resembling *Dhooshivisha*, *Garavisha*, and similar toxicities. Establishing a clear conceptual

correlation between chemical exposure, such as that caused by endosulfan, and these Ayurvedic classifications enables the application of time-tested Ayurvedic interventions for effective management. Bridging this gap is essential to validate the relevance of classical Ayurvedic treatments in the context of modern environmental toxins, such as endosulfan, and to integrate these protocols into contemporary healthcare frameworks. Ultimately, this cross-disciplinary analysis deepens our understanding of long-term pesticide poisoning and opens avenues for developing holistic treatment strategies that combine the strengths of Ayurveda and modern medicine.

Materials and Methods

A comprehensive literature review was conducted to gather information from both Ayurvedic classical texts and modern scientific studies related to Endosulfan toxicity and its Ayurvedic interpretation. Primary Ayurvedic sources, including the *Charaka Samhita*, *Sushruta Samhita*, *Ashtanga Hridaya*, were reviewed to identify references on *Visha*, *Garavisha*, *Dhooshivisha*, and *Janapadodhwamsa*. For modern correlation, a review of research articles, governmental and WHO reports, and toxicological studies was undertaken. The databases PubMed and Google Scholar were searched using keywords such as Endosulfan poisoning, *Dhooshivisha*, *Garavisha*, *Janapadodhwamsa*, and Ayurveda. Information on the mechanism of toxicity, exposure routes, clinical manifestations, and long-term health outcomes of Endosulfan was extracted and interpreted through Ayurvedic conceptual frameworks.

AIM AND OBJECTIVES

To analyze Endosulfan-induced toxicity from an Ayurvedic perspective and establish its conceptual correlation with *Garavisha*, *Dhooshivisha*, and *Janapadodhwamsa*.

LITERATURE REVIEW

Janapadodhwamsa

Janapadodhwamsa denotes the large-scale destruction of human populations or communities resulting from natural calamities or man-made events, such as epidemics. According to *Charaka*, the cause of *Janapadodhwamsa* lies in the disturbance of universally shared factors, *Vayu* (air), *Jala* (water), *Desha* (land), and *Kala* (time or season), which affect all individuals residing in a specific geographic area.^[10] It is noteworthy that this concept has been elaborated only by *Charaka* among the *Brihatrayi*. Other Acharyas, including *Sushruta* and *Vagbhata*, do not describe *Janapadodhwamsa* as a separate concept, which highlights *Charaka's* unique contribution in emphasizing environmental and ecological determinants of mass morbidity.

Garavisha

Acharya Charaka mentions that *Garavisha* refers to a type of poison created by combining various toxic substances or artificially prepared poisons, in addition to the primary classification of *Visha* into *Sthavara* (plant-based) and *Jangama* (animal-based) types. It is artificially prepared using a mixture of various substances to produce various diseases. Due to the slow digestive nature of this type of *Visha*, it does not cause immediate death upon consumption.^[11]

Types of Garavisha

1. *Nirvisha Dravya Samyoga Kritam* - This refers to the combination of two non-toxic substances that, when combined improperly, can act as a poison. An example is *Viruddhahara* (incompatible food combinations), which falls under this category.^[12]
2. *Savisha Dravya Samyoga Kritam* - This type arises from the combination of inherently toxic substances. Such mixtures are considered *Kritrima Visha* (artificial poisons).^[12]

Mode of administration of Garavisha

Anna (food), *pana* (drinks), *anulepana* (unguents), *utsadana* (massaging powder), *dantakashta* (tooth brush), *parisheka* (medicated bathing powder), *kashaya* (decoction), *anjana* (collyrium), *nasya* (nasal drops), *vastra* (dresses), *dhuma* (fumigation), *shayya* (beds), *abharana* (ornaments), *paaduka* (footwears).^[13]

Lakshanas of Garavisha (Table 1)

Dhooshivisha

Dhooshivisha can be attained by *sthavara* (plant-origin poison), *jangama* (animal-origin). Chakrapani describes *Dhooshivisha* as “*Kalantara Prakopi Visham Dhooshivisha*,” indicating a type of poison that produces symptoms after a delay.^[9] The term *Dhooshivisha* is derived from two components: *Dhooshi*, which implies something denatured, weakened, altered, latent, or slowly acting on the body; and

Visha, meaning poison.^[18] Due to its reduced potency compared to more virulent poisons and the obstructive (*avarana*) influence of *Kapha*, these milder toxins tend to persist in the body for a prolonged duration. This results in a delayed onset of symptoms and progressive toxicity over time, typically without causing immediate or fatal consequences.^[19,20]

Purvarupa (Prodromal symptoms) of Dhooshivisha

Excessive sleepiness (*Nidra*), heaviness in the body (*Guruta*), frequent yawning (*Vijrambha*), looseness or instability of joints (*Vishlesha*), goosebumps or skin tingling (*Romaharsha*), and generalized body ache (*Angamarda*).^[21]

Lakshana (Symptoms) (Table 2)

Acharya Sushruta has described various clinical symptoms that arise when *Dhooshivisha* becomes lodged in the deeper bodily tissues (*Dhatus*).^[27] (Table 3)

Upadrava (complications) of Dhooshivisha

Jwara (fever), *daha* (burning sensation), *hikka* (hiccup), *anaha* (distension of abdomen), *sukra kshaya* (reduction in sperm count), *khotha* (swelling or inflammation), *atisara* (diarrhea or excessive bowel movements), *murchha* (fainting or loss of consciousness), and *hridroga* (heart-related conditions or cardiac disorders). *unmada* (insanity), *kampana* (tremor).^[28]

Endosulfan poisoning

Extensive experimental, clinical, and epidemiological investigations collectively establish that endosulfan acts as a persistent, bioaccumulative organochlorine toxin with severe implications for human health and the environment.^[48] Acute exposure predominantly manifests as neurotoxicity, driven by endosulfan's antagonistic action on GABA_A receptors.^[49] This leads to generalized seizures, altered consciousness, metabolic derangements, respiratory dysfunction, and cardiovascular instability, observations that are consistently reported across poisoning case series and toxicology studies.^[50,51]

Table No.1 Lakshanas of Garavisha according to different Acharyas

Yogaratanakara	Charaka samhita	Ashtanga hrudaya
Symptoms appear within 15 days to 1 month of intake Laziness, heaviness, cough, difficulty in breathing, fatigue or weakness, hemorrhage oedema, yellowing of eyes. ^[14] <i>Panduroga</i> (anemia), <i>kushta</i> (skin diseases), <i>mandagni</i> (low digestive fire), pain in <i>marmasthana</i> (vital points), <i>adhmana</i> (bloating), <i>grahani</i> , <i>yakshma</i> (wasting diseases), <i>gulma</i> (abdominal lumps), <i>jwara</i> (fever). ^[15]	Anaemia, weight loss, weak digestion, toxicity, heart palpitations, bloating, swelling in the limbs, ascites, <i>grahani-dosa</i> , tuberculosis, <i>gulma</i> , wasting disorders, and recurring fever. Mentally, they experience disturbing dreams featuring animals like cats, jackals, mongooses, and monkeys, or scenes of dried rivers and withered trees. A dark-skinned person may dream of being fair, and vice versa. They may also dream of being disfigured, missing ears or nose or having distorted sense organs. ^[16]	Pallor, emaciation, loss of digestive power, cough, breathlessness, fever, and abnormal upward Vata movement. The patient tends to oversleep, worry, and develop enlarged liver, spleen, and abdomen, with related disorders. A weak voice, general debility, lethargy, body swelling, abdominal distension, and dryness of hands and feet are common. Disturbed dreams occur, featuring animals like jackals, cats, snakes, and monkeys, as well as dry trees and reservoirs. The person may see themselves as having a changed complexion and distorted facial features. ^[17]

Table No.2 Symptoms of *Dhooshivisha*

Charaka ^[22]	Susruta ^[23]	Ashtanga hridaya ^[24]	Yogaratanakara ^[25]	Bhavaprakasha ^[26]
Vitiating of blood <i>(Raktadushti)</i> • Skin conditions: <i>Aru</i> (scalp eczema), <i>Kitibha</i> (psoriasis), <i>Kotha</i> (urticaria) • Involvement of all <i>Tridoshas</i> • May lead to death if untreated	Loose, discoloured, foul-smelling stools • Bad taste in mouth, excessive thirst • Fainting, vomiting, stammering • Signs of <i>Dusyodara</i> (abdominal enlargement) • Psychological effects: fear, grief, timidity • Hair loss-appears like a featherless bird • <i>Kapha-Vata</i> disorders (if in stomach); <i>Vata-Pitta</i> disorders (if in colon) • Toxin spreads to <i>Rasa</i> and other <i>Dhatus</i> , causing tissue disorders	Multicoloured loose stools • <i>Raktadushti</i> (blood vitiating), excessive thirst • Loss of taste and appetite • Fainting, vomiting, stammering, loss of consciousness • <i>Dusyodara</i> • Hair loss (featherless appearance) • <i>Kapha-Vata</i> disorders (in <i>Amasaya</i>), <i>Vata-Pitta</i> (in <i>Pakvasaya</i>) • Toxin spreads to <i>Dhatus</i> , causing systemic symptoms	Sleeplessness, body heaviness, yawning • Aches, horripilation (<i>Romancha</i>) • Food toxicity (<i>Annamada</i>), indigestion (<i>Avipaka</i>), loss of taste (<i>Aruchi</i>) • Circular skin eruptions (<i>Mandala</i> , <i>Kotha</i>) • Muscle wasting, swelling of limbs • Fainting, vomiting, diarrhoea, breathlessness • Thirst, fever, <i>Dusyodara</i> , anaemia (<i>Pandutva</i>), emaciation • Diminished digestive fire (<i>Mandagni</i>) • May cause: insanity (<i>Unmada</i>), abdominal obstruction (<i>Anaha</i>), semen loss (<i>Sukraksaya</i>), stammering (<i>Gadgada</i>), skin diseases (<i>Kustha</i>), and chronic systemic disorders like <i>Udararoga</i> , <i>Grahani</i> , <i>Ksaya</i> , <i>Jvara</i> , <i>Sotha</i> , <i>Visphotaka</i>	Loose, discoloured, foul stools • Bad taste, thirst, fainting, giddiness • Vomiting, stammering, restlessness • Uncoordinated, improper activity • Hair loss (resembles featherless bird) • <i>Kapha-Vata</i> disorders (in <i>Amasaya</i>); <i>Vata-Pitta</i> (in <i>Pakvasaya</i>) • Toxin affects <i>Rasa</i> and other <i>Dhatus</i> • When aggravated: <i>Annamada</i> , indigestion, <i>Aruchi</i> , skin rashes, muscle wasting, limb swelling • Fainting, vomiting, diarrhoea, breathlessness, thirst, fever, <i>Dusyodara</i> • Can lead to: <i>Unmada</i> , <i>Anaha</i> , <i>Sukraksaya</i> , <i>Gadgada</i> , <i>Kustha</i> , and other systemic illnesses

Table No: 3 *Dhatu*-wise Clinical features of *Dhooshivisha*

S.N	Dhatus	Clinical features
1	Rasa	<i>Annaasradha</i> (aversion to food), <i>arochaka</i> (anorexia), <i>avipaka</i> (indigestion), <i>angamarda</i> (generalized body pain), <i>jwara</i> (fever), <i>hrillasa</i> (nausea or queasiness), <i>tripti</i> (false sense of fullness or early satiety), <i>gaurava</i> (bodily heaviness), <i>hridroga</i> (heart-related disorders), and <i>pandu</i> (pallor or anemia)., <i>margoparodha</i> (obstruction in channels), (<i>karshya</i>) emaciation, <i>vairasya</i> (abnormal taste), <i>angasada</i> (lassitude), <i>akalajavali</i> (premature wrinkles), <i>palita</i> (greying of hairs), <i>adarsana</i> (loss of vision)
2	Rakta	<i>Kushta</i> (leprosy), <i>Visarpa</i> (erysipelas), <i>pidaka</i> (boils), <i>masaka</i> (moles), <i>nilika</i> (bluishness), <i>thilakalak</i> (freckles), <i>nyaccha</i> (freckles), <i>vyanga</i> (dark shade), <i>indralupta</i> (alopecia), <i>pleeha</i> (splenomegaly), <i>vidradhi</i> (abscess), <i>gulma</i> , <i>vatashonita</i> , <i>arsha</i> (piles), <i>arbudha</i> (tumour), <i>angamardha</i> (body-ache), <i>asrigdara</i> (meno- metrorrhagia), <i>rakthapitta</i> and also inflammation in anus, mouth and penis (<i>guda-mukha-medrapaka</i>)
3	Mamsa	<i>Adhimamsa</i> (hypertrophy of muscles), <i>arbuda</i> (tumour), <i>arsha</i> (piles), <i>adhijihva</i> , <i>upajihva</i> , <i>upakusa</i> , <i>galashundika</i> (enlarged uvula), <i>alaji</i> , <i>mamsasanghata</i> , <i>oshta prakopa</i> (disorders of lips), <i>galaganda</i> (goitre), <i>gandamala</i> (cervical lymphadenitis)
4	Medo	<i>Granthi</i> (cyst), <i>vridhhi</i> (scrotal enlargement), <i>galaganda</i> (goitre), <i>arbuda</i> (tumour), <i>medoja oshtaprakopa</i> (disorders of lips caused by fat), <i>madhumeha</i> (diabetes), <i>athisthaulya</i> (obesity), <i>atisweda</i> (excessive perspiration)
5	Asthi	<i>Adhyasthi</i> (extra bony growth), <i>adhidanta</i> (extra tooth), <i>asthitoda</i> & <i>asthisool</i> (pricking & other types of pain in bone), <i>kunakha</i> (disease of nails)
6	Majja	<i>Tamodarsana</i> (seeing darkness or black spots before the eyes), <i>murcha</i> (fainting or loss of consciousness), <i>bhrama</i> (giddiness), <i>netrabhishyandhi</i> (conjunctivitis)
7	Sukra	<i>Klaibya</i> (sterility), <i>apraharsha</i> (impotence), <i>sukrashmari</i> (spermolith), <i>sukrameha</i> , <i>sukradosha</i> (abnormalities of semen)

Long-term exposure produces a distinctly different pattern of systemic involvement owing to its tendency to accumulate in adipose tissue and vital organs.^[48] Research demonstrates persistent endocrine disruption, reproductive abnormalities, hepatic and renal injury, immunological alterations, genotoxic effects, and developmental toxicity.^[50,51] Findings from affected communities particularly those exposed over many years show increased prevalence of congenital anomalies, hormonal disturbances, neurodevelopmental disorders, impaired fertility, and chronic systemic disease, indicating the compound's capacity for multi-organ and transgenerational toxicity.^[51]

Environmental analyses complement these clinical observations by confirming endosulfan's long persistence in

soil, water, and biological systems, enabling extensive bioaccumulation and biomagnification across ecosystems.^[48] This environmental stability directly contributes to prolonged human exposure, even long after cessation of spraying, thereby reinforcing the public-health significance of the toxin.^[48,50]

Death in endosulfan toxicity is usually the result of respiratory arrest following seizures, accompanied by pulmonary oedema, coagulopathy, metabolic acidosis, haemodynamic instability, and hyperglycaemia.^[29] However, such outcomes occur primarily in cases of acute ingestion of concentrated formulations, while low-level, long-term exposure carries minimal risk of fatality.^[30]

Table No.4: Symptoms of Endosulfan poisoning

System Affected	Observed Effects	Remarks
Respiratory	Hypoxia, dyspnoea, and cyanosis.	Occurs only at high-level exposure; likely due to CNS disruption. ^[31]
Cardiovascular	Tachycardia, hypertension, cardiogenic shock, increased cardiac output and peripheral resistance, severe hypotension, and congestive heart failure. ^[32]	Effects seen only at convulsive doses; likely mediated by the CNS.
Metabolic	Metabolic acidosis, hyperglycaemia. ^[31]	Caused by anoxia due to seizures. Not expected at low-level exposure.
Immunological/ Lymphoreticular	Suppressed IgG, IgM, and γ -globulin levels in rats. ^[32]	Suggests immunotoxicity may be a sensitive endpoint. ^[33]
Neurological	Hyperactivity, seizures, decreased respiration, dyspnoea, neurobehavioral and cognitive disorders, hydrocephalus, Parkinson's, and cortical blindness. ^[34]	Most prominent and well-documented effects; seen in both occupational and accidental exposures. ^[34]
Reproductive	Delayed sexual maturity, impaired spermatogenesis, cryptorchidism, testicular necrosis, reduced sperm count. ^[35]	It can be passed in utero or via breastfeeding. ^[36]
Genotoxicity, Cytotoxicity, Teratogenicity	Temporary generation of reactive oxygen species (ROS) and breakage of DNA strands, liver and neuron damage, foetal anomalies like hydrocephalus, microphthalmia, incomplete ossification. ^[37,38]	Shown in animal studies, cytotoxic in multiple cell types.
Carcinogenicity	Linked to breast, uterine, and prostate cancer; mimics oestrogen; destroys Natural killer cells, which suppress tumours. ^[39,40,41]	Significant cancer risk due to hormonal disruption and immune suppression. ^[41]

Table No:5 Symptoms of Endosulfan Toxicity According to Ayurvedic Texts and Contemporary Medical Science

Feature	Garavisha	Dhooshivisha	Endosulfan Poisoning
Origin	Artificial poison – formed by combining two non-toxic substances	Latent or residual poison (natural/artificial origin)	Synthetic organochlorine insecticide
Toxic Nature	Becomes toxic due to unnatural combinations	Toxic due to weakened potency or residual presence	Neurotoxic, hepatotoxic, persistent in the environment and body
Onset of Symptoms	Delayed (15 days to 1-month post-exposure)	Slow, insidious onset with chronic signs	Delayed onset (hours to days), chronic exposure can take months
Purvarupa (Prodrome)	Not explicitly stated	Sleepiness, heaviness, yawning, joint laxity, goosebumps, aches	Headache, dizziness, nausea, fatigue, malaise
Digestive Effects	<i>Mandagni, Adhman, Grahani, Udarrog</i>	Anorexia, Indigestion, Vomiting, Diarrhoea, Ascites	Nausea, vomiting, abdominal cramps, anorexia
Mental/Nervous Impact	Dreams of animals, delusions, memory loss, <i>Unmada</i> in later stages	<i>Unmada</i> (insanity), <i>Murchha</i> (syncope), altered voice	Convulsions, seizures, agitation, confusion, depression, neurodevelopmental delay
Skin & External Signs	Yellow eyes, oedema, paleness, wasting	<i>Kotha, Mandala</i> (patches), pallor, altered complexion	Dermatitis, skin irritation, and sometimes burns on direct contact
Reproductive Effects	Not addressed	<i>Shukrakshaya</i> (sperm depletion)	Endocrine disruption, reproductive toxicity (reduced fertility, foetal abnormalities)
Liver/Spleen Involvement	Enlargement of liver, spleen	Ascites, liver dysfunction	Hepatomegaly, liver enzyme elevation, hepatotoxicity
Fever Profile	<i>Jvara</i>	<i>Vishamajvara</i> (intermittent fever)	Not a core symptom; fever may occur in systemic toxicity
Dream Abnormalities	Prominent: sees cats, jackals, mutilated self	Not emphasized	Not relevant in modern toxicology
Tissue Impact	<i>Dhatukshaya</i> , Oedema	<i>Dhatukshaya, Shotha</i>	Chronic exposure → wasting, immunosuppression, organ damage
Environmental Persistence	Not addressed	Residual action is possible due to latency	Highly persistent, bioaccumulates in food chains
Fatality Potential	Generally, not immediately fatal; chronic deterioration	Rarely fatal; weak cumulative toxicity	High in acute exposure; chronic exposure leads to irreversible neurological damage

Correlation: Relevance of Ayurvedic Descriptions in the Context of Endosulfan Toxicity

The symptomatology of Endosulfan toxicity shows remarkable parallels with the Ayurvedic descriptions of *Dhooshivisha*, *Garavisha*, and *Janapadodhwamsa*, thereby reinforcing the classical applicability of Ayurvedic toxicology in interpreting modern pesticide-induced disorders. Many chronic manifestations of Endosulfan such as neurological impairment,

reproductive dysfunction, metabolic derangements, skin abnormalities, and respiratory complaints mirror the progressive tissue-level damage (*dhatu-dushti*) and multisystem involvement described for *Dhooshivisha*. The pesticide's lipophilic nature and prolonged bioaccumulation closely resemble the slow-acting, residual toxicity of *Dhooshivisha*, which remains dormant in tissues and manifests gradually with nonspecific but persistent symptoms.

Acute or subacute features of Endosulfan poisoning seizures, gastrointestinal irritation, skin burning, or allergic reactions align with patterns of *Garavisha*, which arises from incompatible, artificial combinations and produces relatively quicker systemic disturbances. This dual resemblance reflects the mixed pathophysiology of Endosulfan: an artificially synthesized toxin capable of both immediate and delayed effects. On a broader scale, the environmental persistence, contamination of soil and water, mass morbidity, intergenerational effects, and community-wide health crises observed in Endosulfan-affected regions mirror Charaka's concept of *Janapadodhwamsa*, where vitiation of common environmental factors such as air, water, land, and seasonal patterns leads to widespread disease across populations. This correlation emphasizes that Ayurvedic toxicology offers a sophisticated framework to understand not just individual toxicity, but also ecological and public-health consequences. Thus, mapping the symptoms of Endosulfan poisoning with Ayurvedic categories demonstrates the enduring relevance of classical descriptions in diagnosing, interpreting, and managing modern environmental toxicities, supporting the potential for integrative toxicological and public-health approaches.

Discussion

The clinical and ecological profile of endosulfan exposure presents a multifaceted toxicological problem that resonates strongly with several classical Ayurvedic categories. Modern toxicology identifies endosulfan as a lipophilic, persistent organochlorine pesticide with pronounced neurotoxic, endocrine-disrupting, reproductive, genotoxic and immunotoxic effects. Mechanistically, endosulfan antagonizes GABA_A receptors, causing neuronal hyperexcitability and a low seizure threshold, and it also shows estrogenic/antiandrogenic activity in various experimental systems, effects that help explain both the acute convulsive syndromes and the long-term reproductive and developmental abnormalities seen in exposed populations.^[42]

Acute neurotoxicity is the hallmark of high-dose endosulfan poisoning. Clinical series consistently document generalized tonic-clonic seizures, progression to status epilepticus, respiratory compromise, and secondary metabolic derangements (e.g., metabolic acidosis, hyperglycemia) that can culminate in respiratory arrest and death in severe cases. These acute presentations align with the Ayurvedic description of *visha* effects that produce marked neurological disturbance and potentially fatal outcomes; however, they differ from *Garavisha*'s classic profile in that *Garavisha* is typically associated with delayed or subacute manifestations rather

than immediate fulminant toxicity.⁴³ In contrast, the chronic and subclinical impacts of low-level, long-term exposure to endosulfan bioaccumulation in adipose tissue, persistent low-grade organ dysfunction, endocrine disruption, DNA damage and elevated cancer risk map more closely to the classical concept of *Dhooshivisha*. *Dhooshivisha* denotes a weakened/latent poison that lodges in tissues and manifests gradually, producing multisystem derangements (*raktadushti*, *medodhatu* and *sukra* vitiation, wasting, neurobehavioral change) over time. Contemporary studies reporting reproductive hormone alterations, impaired spermatogenesis, teratogenic effects, and molecular evidence of DNA strand breaks after prolonged exposure provide empirical support for this comparison.^[44]

Beyond individual clinical effects, the large-scale environmental contamination and community-wide health consequences observed in areas of aerial spraying (e.g., Kasaragod) exemplify *Janapadodhwamsa* as formulated in Ayurvedic texts. Charaka's description emphasizes that when common environmental determinants (air, water, land, season) are vitiated, entire populations suffer irrespective of individual constitutions. The epidemiologic signal in endosulfan-affected regions elevated rates of congenital anomalies, neurodevelopmental delay, cancers, and widespread ecosystem harm is concordant with this classical notion and emphasizes the public-health dimension of modern pesticide use. Governmental investigations and independent reviews documenting environmental persistence, food-chain contamination and community morbidity strengthen this parallel.^[45] From a mechanistic and therapeutic standpoint, mapping endosulfan toxicity onto Ayurvedic categories has pragmatic value. If viewed through the *Dhooshivisha* model, management should emphasize long-term detoxification, removal of stored toxins (medicated virechana, basti where indicated), strengthening of *agni* (digestive/metabolic restoration), and *Rasayana* measures to support tissue repair and neuro-immunomodulation. Simultaneously, the *Janapadodhwamsa* framework foregrounds preventive and public-health interventions environmental remediation, safe food/water measures, surveillance of exposed cohorts, and policy measures to prevent future contamination complementing individual clinical care. While classical protocols offer conceptual guidance, any Ayurvedic interventions proposed for endosulfan victims must be validated for safety and efficacy in well-designed clinical or translational studies.^[46]

Limitations of this integrative approach must be acknowledged. First, Ayurvedic nosology and modern toxicology operate with different epistemologies; mapping

concepts is interpretive rather than direct equivalence. Second, much of the epidemiological data from affected regions are heterogeneous and sometimes contested; confounding factors and retrospective designs complicate causal inference. Third, most experimental mechanistic data are from animal or in vitro studies; human longitudinal studies with biomonitoring remain limited. These gaps highlight the need for interdisciplinary research combining classical textual analysis, rigorous toxicology, biomonitoring, and controlled clinical evaluation of Ayurvedic management strategies^[47]. The clinical profile of Endosulfan toxicity shows close resemblance to the Ayurvedic concept of *Dhooshivisha*. Both share the characteristic of gradual accumulation and delayed onset of systemic manifestations. In modern toxicology, chronic Endosulfan exposure leads to progressive impairment of the nervous, reproductive, and endocrine systems due to its lipophilic, bioaccumulative nature. Similarly, *Dhooshivisha* produces multisystemic derangements resulting from the deposition of residual toxins within *dhatu*s (body tissues), manifesting as neurological, metabolic, and reproductive disturbances over time. In contrast, *Garavisha* although also an artificially generated poison, produces relatively quicker manifestations arising from the combination of incompatible substances. This differs from the slow, cumulative pathology of Endosulfan exposure. When viewed on a broader ecological scale, the widespread community-level suffering, environmental contamination, and intergenerational effects seen in Endosulfan-affected regions parallel Charaka's description of *Janapadodhwamsa*, where vitiation of common environmental determinants leads to mass morbidity and ecological imbalance.

Conclusion

This review highlights the profound parallels between chronic Endosulfan toxicity and the Ayurvedic concept of *Dhooshivisha*, both characterized by latent onset, progressive systemic deterioration, and long-term tissue damage. Modern toxicology describes Endosulfan as a lipophilic, bioaccumulative compound that gradually impairs the nervous, reproductive, and endocrine systems with sustained exposure. This closely mirrors the Ayurvedic understanding of *Dhooshivisha*, wherein residual toxins accumulate within *dhatu*s, leading to multisystemic disturbances, neurological, metabolic, and reproductive, over an extended period. While certain acute features of Endosulfan poisoning may resemble *Garavisha*, which arises from the rapid action of incompatible artificial substances, the overall clinical trajectory of Endosulfan is distinctly chronic and cumulative rather than immediate.

Moreover, the large-scale ecological and community-level consequences observed in Endosulfan-affected regions resonate with Charaka's description of *Janapadodhwamsa*, wherein widespread vitiation of air, water, land, and seasonal rhythms results in mass morbidity and environmental imbalance. This integrative perspective not only enriches our understanding of pesticide-induced disorders but also highlights the potential for collaborative approaches in clinical management, preventive strategies, and public health interventions.

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