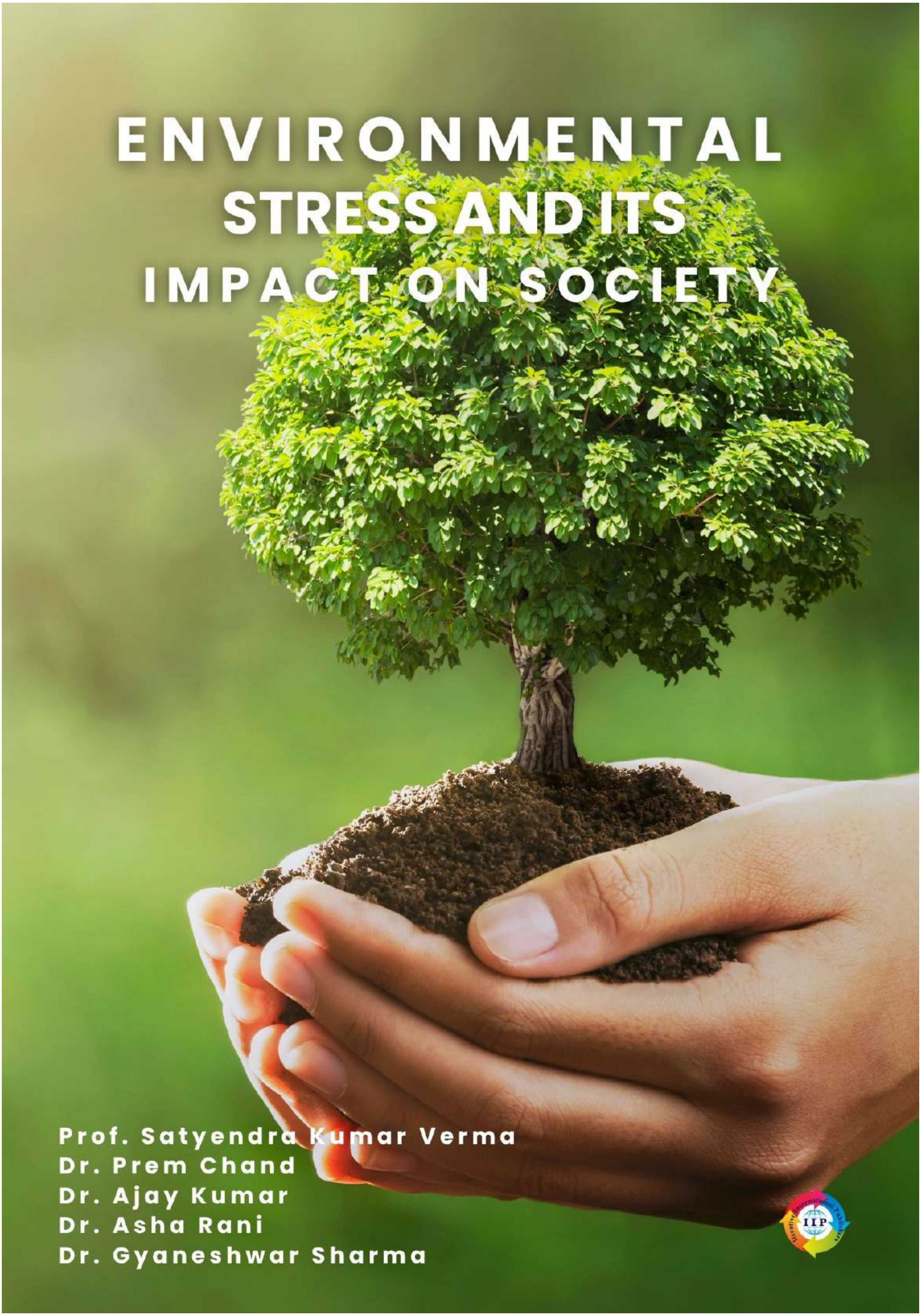
ENVIRONMENTAL STRESS AND ITS IMPACT ON SOCIETY



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Environmental Stress and its Impact on Society

First Volume

Editors

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Preface

The accelerating pace of environmental change has emerged as one of the defining challenges of present time. From the intensification of natural disasters to the slow-onset impacts of climate change, environmental stress is no longer a peripheral concern it is a central force reshaping the niche organization around the world. These changes not only disrupt ecological systems but also affect human health, livelihoods, migration patterns, infrastructure, and social cohesion.

Environmental Stress and Its Impact on Society brings together diverse perspectives from scholars, practitioners, and policymakers to explore the multifaceted relationship between environmental pressures and societal outcomes. This edited volume seeks to provide a comprehensive overview of the ways in which environmental stress manifests across different contexts, and how societies are responding—or failing to respond—to these challenges.

The chapters included here span a range of themes, from climate-induced displacement and urban vulnerability to water insecurity, governance responses, and the psychological impacts of ecological degradation. By drawing on interdisciplinary research and global case studies, this volume aims to foster a deeper understanding of the complex and often unequal effects of environmental stress.

This book would not have been possible without the valuable contributions of our chapter authors, who bring critical insights from a variety of fields including environmental science, life science, agro sciences, biochemistry, biophysics, sociopolitical science, public health, and economics. We are also grateful to the peer reviewers and editorial team whose thoughtful feedback helped shape the final work.

It is our hope that this volume serves as a useful resource for researchers, students, and policy-makers seeking to address the urgent and interconnected challenges posed by environmental stress. As the pressures on natural and human systems continue to mount, informed and collaborative responses are more necessary than ever.

Prof. Satyendra Kumar Verma
Dr. Prem Chand
Dr. Ajay Kumar
Dr. Asha Rani
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Acknowledgment

The compilation of this edited volume, *Environmental Stress and Its Impact on Society*, has been a collaborative effort, and we are deeply grateful to the many individuals and institutions that made this work possible.

First and foremost, we would like to thank the contributing authors whose research, insights, and dedication have formed the foundation of this book. Their interdisciplinary approaches and commitment to addressing the pressing issues of environmental stress have enriched this volume in significant ways.

We are also indebted to the peer reviewers who provided thoughtful and constructive feedback during the review process. Their contributions greatly enhanced the quality, clarity, and coherence of the chapters.

Our sincere appreciation goes to the academic institutions and research organizations that supported this work, both logistically and intellectually. Their encouragement and resources enabled us to bring together diverse voices from across disciplines and regions.

We would like to express our sincere thanks to Prof. Shri Prakash Singh, President, Management Committee, Mr. Raghvendra Pratap Singh, Manager, Prof. Ram Asare Singh, Principal Tilak Dhari Post Graduate College, Jaunpur, for their invaluable support, encouragement and guidance throughout the preparation of this edited book. Their contributions have been instrumental in bringing this work to successful completion.

We would like to thanks our supporting staff Mr. Udai Pratap Singh, Mr. Shyam Lal, Mr. Om Prakash Pal for their continuous logistical support.

Lastly, we extend our gratitude to our families and colleagues for their patience, encouragement, and unwavering support throughout the long process of bringing this book to life.

We would also like to acknowledge the efforts of the editorial and production teams, whose professionalism and attention to detail ensured the successful completion of this volume.

It is our hope that this book will contribute meaningfully to the ongoing dialogue on environmental change and societal resilience, and serve as a valuable resource for scholars, students, and practitioners alike.

Prof. Satyendra Kumar Verma
Dr. Prem Chand
Dr. Ajay Kumar
Dr. Asha Rani
Dr. Gyaneshwar Sharma

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MELATONIN REGULATE LIPOPOLYSACCHARIDE INDUCED INFLAMMATION AND REPRODUCTIVE HEALTH

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Abstract

In the last several years, infertility has become a problem that significantly affects the reproduction of both humans and animals. A major pathologic cause of male sterility is an inflammatory response triggered by a genital meatus infection. Orchitis is associated with certain bacterial infections of the genitourinary tract. The testis may be able to fight off infections since it is an organ with intrinsic immunity. Though some pathogens have also been known to attack the blood–testis barrier, causing inflammatory responses in the seminiferous tubules, sertoli cells in seminiferous tubules form tight junctions that ensure normal spermatogenesis and reduce the risk of infection. The cell walls of bacteria contain lipopolysaccharide (LPS), sometimes referred to as endotoxin. The main pathogenic component of Gram -Ve bacteria is LPS, which may cause a variety of inflammatory reactions in the body. Male infertility can be caused by inflammation-induced dysregulation of sperm and steroid production in the testes. Testicular dysfunction and germ cell death have been demonstrated to by LPS exposure. Infection and inflammation also cause testicular dysfunction in animals and cells treated with LPS. The lipophilic and hydrophilic small molecule called melatonin is synthesized in the pineal gland. Pleiotropic hormone that mostly regulates the immune system, circadian rhythms, seasonal rhythms, sleep, and retinal function. MEL and as well as its metabolites are broad-spectrum antioxidants that increase endogenous antioxidant expression and actively remove reactive oxygen and nitrogen species. Melatonin is providing an effective defence against inflammation and oxidative stress. Antioxidant enzymes are upregulated and free radicals are scavenging increases after melatonin treatment. Melatonin has pleiotropic properties and may be used as a treatment for inflammatory disorders.

Keywords: Lipopolysaccharide, Endotoxin, Melatonin, Reproductive health, Inflammation

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I. INTRODUCTION

Inflammation is a part of the body's immune response, serving as a protective mechanism against infections, injuries, and harmful stimuli. However, when inflammation becomes chronic or dysregulated, it can contribute to several health problems, including reproductive disorders (Asadi et al.,2017, Zhao et al.,2019). The relationship between inflammation and reproductive health is complex, with inflammatory processes influencing the reproductive systems of both male and female (Yang et al.,2020). In the acute inflammation, our body immediate response to tissue damage or microbial infection, characterized by redness, heat, swelling, and pain. In contrast, chronic inflammation occurs when inflammation persists for an extended period, often due to an underlying condition or external factors, it becomes chronic. Chronic inflammation is linked with numerous diseases, including cardiovascular disorders, diabetes, and autoimmune conditions (Skrzypczak and Sałat 2022). In the context of reproductive health, chronic inflammation can negatively impact fertility, sexual function, and pregnancy outcomesm as well (Kumar et al.,2021). Lipopolysaccharides (LPS) are large molecules found in the external membrane of Gram-negative bacteria. They play a key role in activating the immune system, triggering inflammation, and inducing a host of biological responses. LPS is frequently used in experimental models to study inflammation and immune responses because it mimics bacterial infections by stimulating the immune system (Weidner et al.,2013). LPS is widely used in laboratory settings to simulate bacterial infections and study inflammatory diseases. It serves as a model for investigating the molecular pathways underlying inflammation and evaluating potential anti-inflammatory therapies (Cazanga, et al., 2023). Melatonin, a hormone primarily known for regulating sleep-wake cycles, also plays a significant role in modulating inflammation. It is synthesized by the pineal gland in response to darkness and has powerful antioxidant properties, which help in declining of oxidative stress. Which is a key contributor to inflammation. Studies suggest that melatonin exerts anti-inflammatory effects by influencing various molecular pathways, as well as the modulation of pro-inflammatory cytokines and immune cells (Talib et al.,2021). Melatonin has been shown to inhibit the expression of cytokines like TNF-α, IL-6, and IL-1β, which are involved in promoting inflammation. It also interacts with the nuclear factor kappa (NF-κB) -light-chain of activated B cells, which regulates immune responses and inflammation. Additionally, melatonin can enhance the activity of antioxidant enzymes, further mitigating oxidative damage that fuels the inflammatory process (Pandi-Perumal et al.,2006).

II. THE MECHANISM OF LPS-INDUCED INFLAMMATION

1. LPS Structure and Activation of Immune Pathways

Lipopolysaccharide (LPS) is a component of the outer membrane of Gram-negative bacteria, plays a critical role in triggering the immune response. LPS is a complex macromolecule consisting of three major components: the lipid A, the core oligosaccharide, and the O-antigen. The lipid A is the most conserved part of LPS and is responsible for its ability to activate immune responses. It consists of a phosphorylated glucosamine disaccharide backbone, which is attached to fatty acid chains. This region anchors LPS to the bacterial outer membrane and is essential for its immunogenic properties. The core oligosaccharide lies between lipid A and the O-antigen. It is typically composed of a chain of sugars, including heptose and ketodeoxyoctonate (KDO), which are less variable than the O-antigen but still contribute to the immune recognition of LPS. The O-antigen is the most variable part of LPS and consists of repeating units of oligosaccharides. It forms an extended structure that protrudes from the bacterial surface. The O-antigen helps protect bacteria from immune recognition and complements the ability of LPS to stimulate immune responses by enhancing its interaction with specific receptors. LPS is recognized by the innate immune system through pattern recognition receptors (PRRs) that identify pathogen-associated molecular patterns (PAMPs). The most prominent PRR for LPS is Toll-like receptor 4 (TLR4)**,** which is expressed on various immune cells (Akira & Takeda 2004). The TRIF-dependent pathway involves the activation of IRF3 (interferon regulatory factor 3), leading to the production of type I interferons (IFNs), which are important for antiviral defense and modulating the immune response. Excessive LPS activation can lead to harmful inflammatory responses, such as sepsis, where widespread inflammation causes organ dysfunction and failure. LPS also activates the inflammasome, a multi-protein complex in macrophages that triggers the activation of caspase-1 and subsequent release of active IL-1β and IL-18. These cytokines play significant roles in acute inflammation and host defense (Qiao,.et al.,2013).

2. Effects of Lipopolysaccharide on Systemic Inflammation

Lipopolysaccharide (LPS) enters the bloodstream, it activates the immune system, triggering systemic inflammatory responses that can lead to the release of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6). This cascade of events, while crucial for defense against infections, can also result in excessive inflammation, causing damage to organs and tissues. This process is central to conditions such as sepsis, endotoxemia, and other inflammatory diseases. The binding of LPS to TLR4 activates intracellular signaling pathways that lead to the transcription of genes involved in the production of pro-inflammatory cytokines. One of the key signaling pathways activated by TLR4 is the nuclear factor-kappa B (NF-κB) pathway, which induces the production of cytokines such as TNF-α, IL-1β, and IL-6 (Kawai and Akira, 2007). TNF-α is one of the first cytokines produced in response to LPS exposure and plays a pivotal role in driving the inflammatory cascade. It acts on various cells, including endothelial cells, to increase the expression of adhesion molecules and induce the release of other pro-inflammatory mediators. TNF-α also promotes the production of IL-1β and IL-6, further amplifying the inflammatory response (Baldwin, 2001). IL-1β, produced mainly by macrophages and other immune cells, is another crucial cytokine in the inflammatory process. It activates local tissue cells and enhances the production of adhesion molecules, facilitating the recruitment of immune cells to sites of infection or injury. IL-6, on the other hand, is involved in both the acute phase response and the regulation of the immune system. It not only amplifies inflammation but also promotes the synthesis of acute-phase proteins in the liver (Hirano et al.,2021). In the context of systemic inflammation, excessive or prolonged cytokine production can lead to widespread tissue damage. High levels of TNF-α, IL-1β, and IL-6 contribute to endothelial dysfunction, increased vascular permeability, and coagulopathy, which are characteristic features of sepsis and endotoxemia (van der Poll and Opal, 2008). These changes can lead to tissue hypoxia, organ failure, and ultimately death if not properly controlled. LPS-induced systemic inflammation can also affect other organs, including the lungs, kidneys, and liver. In the lungs, the cytokine storm can lead to acute respiratory distress syndrome (ARDS), while in the kidneys, it can result in acute kidney injury (AKI). The liver, as a central organ in the acute-phase response, may also be severely impacted due to excessive cytokine release (Cohen et al., 2007).

3. LPS and Reproductive Health

Lipopolysaccharides (LPS), components of the external membrane of Gram-negative bacteria, have been shown to significantly influence the reproductive system, including ovarian function, sperm quality, early pregnancy outcomes, and overall fertility in both females and males. LPS triggers an immune response by activating toll-like receptor 4 (TLR4), which promote the production of pro-inflammatory cytokines such as TNF-α, IL-1, and IL-6. These cytokines can disrupt normal reproductive processes, leading to ovarian dysfunction, impaired sperm quality, and adverse effects on pregnancy. In females, exposure to LPS can adversely affect the ovarian function by promoting inflammation, oxidative stress, and hormonal imbalance. LPS-induced inflammation may impair the normal development and maturation of oocytes, thereby reducing oocyte quality and the ability to ovulate. Studies have demonstrated that LPS exposure results in altered levels of key reproductive hormones, such as decreased estrogen and progesterone, which are essential for proper ovarian function and fertility. Additionally, LPS has been shown to increase oxidative stress in ovarian cells, further exacerbating damage to ovarian tissue and impairing follicular development (Velez et al., 2021). Ovarian dysfunction due to LPS exposure can thus lead to conditions such as anovulation and infertility. LPS also negatively impacts male fertility by altering sperm quality. The immune response triggered by LPS can lead to increased oxidative stress, which damages sperm DNA, lipids, and proteins, resulting in reduced sperm motility, viability, and morphology. Studies have demonstrated that LPS exposure in animal models can decrease sperm count and motility while increasing sperm abnormalities (Agarwal et al., 2014). Furthermore, LPS-induced inflammation may disrupt the testicular microenvironment, impairing spermatogenesis and leading to defective sperm production. In particular, LPS can lead to the activation of inflammatory pathways in the testes, resulting in decreased testosterone levels and subsequent disturbances in spermatogenesis (Khan Mohammad et al., 2021). These factors collectively contribute to compromised male fertility. In pregnant females, LPS-induced systemic inflammation can activate uterine immune responses, potentially impairing implantation and placental function. This disruption may result in a failure to support normal embryonic development and proper nutrient exchange between the mother and fetus. Research has shown that LPS administration during pregnancy can lead to increased levels of pro-inflammatory cytokines in the uterus, disrupting the local immune environment and preventing successful embryo implantation (Beloosesky et al., 2017). Additionally, LPS-induced inflammation can negatively affect the placental structure and function, leading to complications such as preeclampsia and intrauterine growth restriction. Both male and female fertility are compromised by chronic exposure to LPS and the subsequent inflammatory response. In females, LPS-induced ovarian dysfunction, hormonal imbalances, and impaired oocyte quality can lead to difficulties with conception, while males may experience reduced sperm quality, motility, and count, making fertilization less likely. Moreover, systemic inflammation associated with LPS can contribute to early pregnancy complications, further reducing fertility potential in both sexes. Understanding the mechanisms behind LPS-induced infertility is critical for developing therapeutic strategies to mitigate the effects of chronic infections or endotoxemia on reproductive health.

III. MELATONIN ANTI-INFLAMMATORY PROPERTIES

1. Melatonin and Immune System Modulation

Melatonin, a hormone primarily synthesized by the pineal gland, is widely recognized for regulating circadian rhythms. However, it also plays a significant role in modulating the immune system, particularly through its effects on inflammatory processes. Melatonin exhibits potent anti-inflammatory and immunoregulatory properties, primarily by reducing the production of pro-inflammatory cytokines and enhancing the expression of anti-inflammatory cytokines. Melatonin's immunomodulatory functions are mediated through both direct and indirect mechanisms. It exerts its effects by binding to high-affinity melatonin receptors (MT1 and MT2), which are expressed on various immune cells, including macrophages, lymphocytes, and dendritic cells. This interaction influences intracellular signaling pathways, notably the nuclear factor kappa B (NF-κB) and NLRP3 inflammasome pathways, both of which are central to inflammation regulation.

2. Antioxidant Mechanisms

Melatonin, a neurohormone primarily produced by the pineal gland, is widely recognized for its role in regulating circadian rhythms. However, beyond its Chrono biological function, melatonin exhibits potent antioxidant properties, making it a significant player in protecting cells from oxidative stress and inflammation. Oxidative stress occurs when there is an imbalance between the production of reactive oxygen species (ROS) and the body's ability to detoxify these reactive intermediates or repair the resulting damage. This stress is closely linked to the pathogenesis of various inflammatory conditions, neurodegenerative diseases, cardiovascular disorders, and cancer. Melatonin acts as a direct free radical scavenger. It neutralizes a wide range of ROS and reactive nitrogen species (RNS), including hydroxyl radicals (•OH), hydrogen peroxide (H_2O_2), singlet oxygen ($^1O_2$), peroxynitrite ($ONOO^-$), and nitric oxide (NO•). This direct scavenging capacity is attributed to melatonin's electron-rich indole ring, which donates electrons to neutralize free radicals (Reiter et al., 2000). Moreover, unlike many classical antioxidants, melatonin does not undergo redox cycling, which means it does not become a pro-oxidant after neutralizing free radicals. Instead, its metabolites, such as N1-acetyl-N2-formyl-5-methoxykynuramine (AFMK), also exhibit antioxidant properties, creating a cascade of protective effects known as the "melatonin antioxidant cascade" (Tan et al., 2007). In addition to directly scavenging ROS, melatonin modulates the expression and activity of antioxidant enzymes. It upregulates the expression of key antioxidant enzymes such as superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase, thereby enhancing the cellular antioxidant defense system (Hardeland, 2005). This modulation is partly mediated through melatonin's interaction with its membrane receptors (MT1 and MT2), which influence intracellular signaling pathways like the nuclear factor erythroid 2-related factor 2 (Nrf2) pathway—a crucial regulator of cellular antioxidant response. Furthermore, melatonin plays a vital role in modulating inflammatory processes that are exacerbated by oxidative stress. ROS are known to activate redox-sensitive transcription factors such as nuclear factor-kappa B (NF-κB), which upregulates the expression of various pro-inflammatory cytokines, chemokines, and adhesion molecules. Melatonin inhibits the activation of NF-κB, thereby suppressing the synthesis of inflammatory mediators such as tumor necrosis factor-alpha (TNF-α), interleukins (IL-1β, IL-6), and inducible nitric oxide synthase (iNOS) (Carrillo-Vico et al., 2013). This anti-inflammatory action further reduces ROS production, breaking the vicious cycle between inflammation and oxidative stress. Melatonin's ability to cross all biological membranes and reach subcellular compartments, including mitochondria, enhances its antioxidant effectiveness. Within mitochondria—the primary source of ROS—melatonin stabilizes mitochondrial membranes, maintains electron transport chain function, and prevents mitochondrial DNA damage, preserving cellular energy metabolism (Acuna-Castroviejo et al., 2001).

3. Regulation of NF-κB Pathway

One of the key actions of melatonin is the inhibition of NF-κB, a transcription factor that regulates the expression of many pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and interleukin-1 beta (IL-1β). NF-κB is typically activated in response to stress, infection, or injury, promoting the expression of genes involved in inflammation. Melatonin suppresses this pathway by preventing the degradation of its inhibitory protein IκBα, thus reducing the translocation of NF-κB into the nucleus and the subsequent production of pro-inflammatory cytokines (Reiter et al., 2017). Furthermore, melatonin downregulates the NLRP3 inflammasome, a multiprotein complex involved in the activation of caspase-1 and the maturation of IL-1β and IL-18. Over activation of the NLRP3 inflammasome is associated with various chronic inflammatory and autoimmune diseases. Melatonin inhibits this inflammasome by reducing mitochondrial reactive oxygen species (ROS) production and improving mitochondrial function, thereby mitigating the inflammatory response (Hardeland, 2018). Simultaneously, melatonin enhances the production of anti-inflammatory cytokines, such as interleukin-10 (IL-10). IL-10 is crucial in limiting host immune responses to pathogens, thereby preventing damage to the host (Carrillo-Vico et al., 2013). Additionally, melatonin promotes the polarization of macrophages from the pro-inflammatory M1 phenotype to the anti-inflammatory M2 phenotype. M2 macrophages secrete IL-10 and transforming growth factor-beta (TGF-β), contributing further to tissue repair and resolution of inflammation. Overall, melatonin acts as a key immunoregulatory molecule by suppressing pro-inflammatory signaling pathways and promoting anti-inflammatory responses.

4. Melatonin and Inflammatory Diseases

Melatonin exhibits significant antioxidant, anti-inflammatory, and immunomodulatory properties, making it a promising therapeutic agent in several diseases, including rheumatoid arthritis (RA), cardiovascular diseases (CVD), and neurological conditions. In rheumatoid arthritis, melatonin plays a dual role. While some studies suggest melatonin may exacerbate RA by enhancing pro-inflammatory cytokine production, others report its anti-inflammatory and antioxidant actions can reduce joint inflammation and oxidative stress (Hardeland et al.,2018). For instance, melatonin has been shown to downregulate NF-κB signaling, thereby decreasing inflammatory mediators like TNF-α and IL-6 (Maestroni, 2001). Melatonin exhibits cardioprotective effects by mitigating oxidative stress and improving endothelial function. It reduces blood pressure, inhibits LDL oxidation, and enhances nitric oxide availability, thereby supporting vascular health (Reiter et al., 2016). In models of myocardial ischemia-reperfusion injury, melatonin administration significantly reduces infarct size and apoptosis through activation of the AMPK and SIRT1 pathways (Dominguez-Rodriguez et al., 2012). Neurologically, melatonin has shown neuroprotective potential in conditions like Alzheimer's disease (AD), Parkinson's disease, and stroke. It inhibits β-amyloid aggregation, reduces tau hyperphosphorylation, and counteracts mitochondrial dysfunction in AD (Shin et al.,2023). Additionally, its free radical scavenging ability supports neuronal survival in neurodegenerative processes.

IV. MELATONIN AND LPS-INDUCED INFLAMMATION

1. Studies on Melatonin and LPS-Induced Inflammation in Animal Models:

Several studies have explored the effects of melatonin administration on the inflammatory response induced by lipopolysaccharide (LPS) in animal models, demonstrating its potential anti-inflammatory properties. LPS, a component of Gram-negative bacteria, is often used to induce acute inflammation in experimental models, mimicking sepsis and other inflammatory conditions. Mehrzadi, et al. (2023) found that melatonin administration significantly reduced pro-inflammatory cytokine levels, such as TNF-α and IL-1β, in rats treated with LPS. The authors proposed that melatonin's antioxidant properties, which mitigate oxidative stress, play a key role in this anti-inflammatory effect. Similarly, a study by Qin et al.,2012) in mice showed that melatonin decreased LPS-induced serum levels of IL-6 and TNF-α, suggesting an inhibitory effect on the cytokine storm associated with inflammation. This study highlighted melatonin's ability to modulate both innate immune responses and inflammatory mediators. Further investigation by Ling et al. (2023) demonstrated that melatonin pre-treatment in rats attenuated the elevated levels of nitric oxide (NO) and pro-inflammatory cytokines following LPS exposure. This study suggested that melatonin might exert its effects by modulating nuclear factor-kappa B (NF-κB), a key signaling pathway involved in inflammation. Overall, these studies support the notion that melatonin could serve as a potential therapeutic agent for inflammatory conditions, particularly in sepsis and other LPS-induced inflammatory responses in animal models.

2. Impact on Cytokine Levels

Melatonin inhibits the activation of nuclear factor-kappa B (NF-κB) and mitogen-activated protein kinases (MAPKs), key signaling pathways involved in the production of pro-inflammatory cytokines (Reiter et al., 2016). Additionally, melatonin promotes the secretion of anti-inflammatory cytokines like IL-10, which helps counteract the effects of pro-inflammatory mediators (Carrillo-Vico et al., 2013). Through these mechanisms, melatonin has the potential to mitigate the harmful inflammatory response triggered by LPS and restore immune balance.

3. Tissue Protection

Melatonin, a effective antioxidant and anti-inflammatory agent, has been shown to protect various organs from the harmful effects of lipopolysaccharide (LPS)-induced inflammation. LPS is a bacterial endotoxin known to induce systemic inflammatory responses, which can damage organs like the liver, kidneys, lungs, and reproductive organs. Studies have demonstrated that melatonin alleviates oxidative stress and inflammation in the liver by reducing pro-inflammatory cytokines and restoring antioxidant enzyme activity (Reiter et al., 2016). In the kidneys, melatonin mitigates kidney injury by inhibiting inflammatory pathways, such as NF-kB, and promoting autophagy (Sener et al., 2005). It also protects the lungs by reducing the secretion of pro-inflammatory mediators and improving lung function during LPS-induced sepsis (Di et al., 2020). In reproductive organs, melatonin mitigates LPS-induced damage by modulating immune responses and reducing oxidative stress (Dong et al., 2020). These effects underscore melatonin's potential in protecting organs during systemic inflammation

4. Melatonin and Reproductive Health

The pineal gland is the primary source of the lipophilic and hydrophilic tiny molecule known as melatonin (Hardeland, 2008). It is pleiotropic hormone, primarily responsible for controlling biological functions like sleep, circadian rhythms, seasonal rhythms, and retinal function, as well as the immunological system (Jockers et al., 2016). According to Hosseinzadeh et al. (2018), Melatonin and its metabolites are broad-spectrum antioxidants that not only eliminate reactive oxygen and nitrogen but also boost endogenous antioxidant expression and activity. Antioxidation can also influence certain pathophysiological processes, including inflammation, apoptosis, and cancer. Decreases in Melatonin secretion levels due to genetic defects or illnesses can result in a number of illnesses, including breast cancer (Kubatka et al., 2018), metabolic diseases (Karamitri & Jockers, 2019), major depressive disorders (De Crescenzo et al., 2017), insomnia (Grima et al., 2018), and inflammation (Hardeland et al., 2018). Melatonin enhanced the antioxidant capacity of the testicles (SOD, CAT) and decreased nitro-oxidative stress (Nitrate, TNFα) to lessen the pathological alterations brought on by LPS. Additionally, through upregulating SIRT-1 expression, melatonin prevented LPS-induced apoptosis, inflammation (NF-kB/COX-2), and nitro-oxidative stress (Bai et al.,2016, Kumar et al.,2021).

V. CONCLUSION

LPS induces systemic inflammation by binding to TLR4, triggering the activation of pro-inflammatory cytokines like TNF-α, IL-1β, and IL-6. The excessive release of these cytokines can lead to severe systemic consequences, including organ damage. It is crucial for developing therapeutic strategies to modulate the inflammatory response and prevent complications associated with conditions like sepsis and endotoxemia. Melatonin is a powerful agent against oxidative stress and inflammation. It leads to free radical scavenging and upregulation of antioxidant defenses. Melatonin have pleiotropic effects offer therapeutic potential against inflammatory disorders although dose, timing, and disease stage critically may influence its efficacy.

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HEAVY METAL TOXICITY: A GROWING THREAT TO HUMAN HEALTH

Abstract

Heavy metals are significant environmental pollutants that pose a substantial threat to ecosystems and human health. These elements, including arsenic, lead, mercury, and cadmium, are toxic even at low concentrations due to their bio-accumulative and non-biodegradable nature. While some heavy metals are essential in trace amounts for biological functions, excessive exposure can lead to severe health consequences. Heavy metals enter the environment through both natural processes and human activities such as mining, industrial emissions, and agricultural practices. Once released, they contaminate air, water, and soil, making their way into the food chain and resulting in chronic toxicity. Exposure to heavy metals can adversely affect multiple bodily systems, including the lungs, kidneys, liver, reproductive system, and immune system. Furthermore, plants may accumulate these metals, further exacerbating human exposure through the consumption of contaminated food. This chapter provides a comprehensive overview of the sources, pathways, and toxicological impacts of heavy metals, underscoring the urgent need for effective pollution management and regulatory policies to mitigate their harmful effects on the environment and public health.

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I. INTRODUCTION

Heavy metals are regarded as highly dangerous environmental contaminants, presenting considerable threats to ecosystems, biodiversity, and human health. Their harmful effects can disturb ecological equilibrium, impede flora and fauna development, and pollute natural resources. A pollutant is defined as any material that adversely impacts the environment, reduces its quality, harms living species, and, in extreme instances, results in fatalities. For a material to be designated as a pollutant, it must exceed a defined threshold referred to as the critical level or tolerance limit. Upon surpassing this threshold, contaminants such as heavy metals collect in the air, water, or soil, resulting in enduring ecological harm. In contrast to biodegradable contaminants, heavy metals endure in the environment, rendering their management and remediation more difficult.

Heavy metals are elements characterized by their high atomic weight and density. They naturally occur in the Earth's crust and are often found in trace (10 mg/kg or mg/L) or ultra-trace (1 µg/kg or µg/L) concentrations in air, water, soil, and biological systems. While the term "heavy metals" generally refers to dense metals, it also encompasses some toxic metalloids like arsenic (As), which can be harmful even at low exposure levels.

Although they are naturally present, most environmental contamination and human exposure to heavy metals result from human activities. Mining, smelting, industrial emissions, and the use of metal-based compounds in agriculture significantly contribute to the release of these metals into the environment. Once introduced, they persist due to their non-biodegradable nature, accumulating in ecosystems and posing serious health risks to humans and wildlife. Managing heavy metal pollution requires stringent regulations and the implementation of sustainable practices to mitigate their harmful effects.

According to ATSDR's (Agency for Toxic Substances and Disease Registry) Substance Priority List (2022), arsenic (As), lead (Pb), mercury (Hg) and cadmium (Cd) are most toxic among all the heavy metals. Besides, nickel, chromium, asbestos, uranium, thorium and copper also produce toxicity. Some heavy metals are either essential nutrients (e.g. iron, cobalt, and zinc), or relatively harmless (e.g. ruthenium, silver, and indium), but can be toxic if exposed to higher amounts.

In recent years, there has been growing ecological and public health concerns regarding environmental poisoning by these metals. Heavy metal contamination poses a significant threat to environmental quality and human health, particularly in developing nations such as India and China. Heavy metals are known for their **bio-accumulative** nature, meaning they persist in the environment without breaking down or being easily metabolized. As a result, their concentrations tend to increase as they move up the ecological food chain — starting from producers like plants and algae, and then passing on to herbivores and higher-level consumers. This progressive buildup is referred to as **biomagnification.** Since they are non-degradable and bio-accumulative nature, health burden on the population has increased significantly.

The accumulation of heavy metals in soils poses significant concerns for agricultural production, adversely affecting food safety, crop growth due to phytotoxicity, and the health of soil organisms such as earthworms, rodents, and insects. Metal toxicity significantly impacts plants and, thus, affects ecological systems in which plants are an essential component. In terrestrial environments, plant roots serve as the primary point of contact for absorbing heavy metal ions from the soil. However, in aquatic ecosystems, the entire plant body remains exposed to these ions, leading to a more widespread uptake. This dual exposure mechanism makes aquatic plants particularly vulnerable to heavy metal contamination, contributing further to the accumulation of these toxic elements in the ecosystem. Heavy metals can enter the human tissues via inhalation, diet, and direct skin-absorption due to manual handling.

II. BIOLOGICAL ROLE OF HEAVY METALS

Heavy metals are also beneficial for organisms. Certain derivatives of heavy metals, including arsenic, platinum, and ruthenium, are used as anticancer drugs since ancient times. Iron (anti-malarial), bismuth (used for gastric ulcers), antimony (anti-protozoal) and gold (anti-arthritic) are other heavy metals used in medicine. Also, zinc, copper, gold and silver are recognized as anti-inflammatory agents. *Various heavy metals and their physiological effects in body are shown in Table 1.*

Certain metals, such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn), serve as essential micronutrients. They play a crucial role in various biochemical and physiological processes in both plants and animals. These metals contribute to enzyme activation, photosynthesis, respiration, and other metabolic activities. They are essential components of some enzymes and also contribute significantly to oxidation-reduction processes. Insufficient availability of certain micronutrients leads to various deficiency illnesses or syndromes. Nonetheless, its accumulation beyond the requirements of plants and animals leads to harmful effects.

Copper is a vital component integrated into many metalloenzymes that participate in glucose metabolism, haemoglobin synthesis, catecholamine production, and the cross-linking of collagen, elastin, and keratin. Numerous enzymes incorporate zinc, including carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase, and RNA polymerase. Zinc is essential for preserving ribosomal integrity. Nickel is a constituent of the enzyme urease, which is vital for its functionality and consequently for the health of animals. Manganese is crucial in the enzymatic processes of malic dehydrogenase and superoxide dismutase (SOD). It is also essential for splitting of water in photosystem (PS-II) and for. In plants, cobalt complexes are present as vitamin B12. Iron is a important metal element in numerous metabolic processes. It is a constituent of heme-containing proteins, including haemoglobin and myoglobin.

Other metals such as aluminium (Al), indium (In), antinomy (Sb), arsenic (As), thallium (Tl), barium (Ba), beryllium (Be), bismuth (Bi), germanium (Ge), gold (Au), lead (Pb), lithium (Li), mercury (Hg), nickel (Ni), platinum (Pt), strontium (Sr), cadmium (Cd), gallium (Ga), tellurium (Te), tin (Sn), titanium (Ti), vanadium (V), silver (Ag), and uranium (U) have no established biological functions and are considered as **non-essential metals.**

Table 1: Physiological importance of heavy metals
(Adopted from Mehrandish et al, 2019)

Heavy metals	Biological Effect
Iron	Oxygen transfer; Contributes to metabolism as a constituent of certain proteins/enzymes.
Zinc	Takes part in drug metabolism, facilitates the mobilization of vitamin A from the liver, and contributes to a defensive mechanism in bacteria against free radical damage.
Copper	Plays a crucial function in the metabolism and is vital for preserving the integrity of the skin, blood vessels, epithelium, and connective tissues throughout the body.
Chromium	Crucial in the metabolism of lipids and carbohydrates. It promotes the synthesis of fatty acids and cholesterol. It is also essential in the function of insulin and glucose metabolism.
Cobalt	An essential part of vitamin B12 and involved in hematopoiesis

Molybdenum	Serves as an electron carrier in enzymes that facilitate the reduction of nitrogen and nitrate. Essential for the metabolism of sulfur-containing amino acids.
Selenium	A functional mineral in immune system.
Manganese	Contributes to the metabolism of macronutrients. It facilitates the digestion and utilization of proteins and amino acids, as well as the metabolism of cholesterol and carbohydrates.
Magnesium	It is essential for energy generation and regulating electrolyte equilibrium. Is crucial for appropriate neuromuscular activities and the transport of calcium and potassium ions.
Therapeutic effects	
Arsenic, Platinum, Ruthenium	Anti-cancer
Bismuth	Stomach ulcer
Gold	Anti-arthritis
Iron	Anti-malaria
Copper, Zinc, Gold, Silver	Anti-inflammatory

Sources of Contamination of Heavy Metals: Heavy metals occur naturally in the Earth's crust in small quantities. Nonetheless, human activities are the primary sources of their pollution. Environmental contamination may arise from metal corrosion, air deposition, sediment resuspension, soil erosion & leaching of heavy metals. Industrial sources include metal processing in refineries, coal combustion in power plants, high voltage transmission lines, petroleum burning, nuclear power facilities, plastics production, wood preservation, textiles manufacturing, microelectronics and paper processing facilities. Please keep in mind that some Natural events, such as weathering and volcanic eruptions, also contribute to heavy metal contamination.

There are different sources of heavy metals in the environment which are described below in details:

1. **Natural Sources of Heavy Metals:** The Earth's crust serves as the primary reservoir of heavy metals, making their presence in soil a natural consequence of the weathering of rocks. The type of rock and the prevailing climatic conditions significantly influence the composition and concentration of these metals. Geological formations, particularly igneous and sedimentary rocks, are the principal natural sources. Volcanic eruptions are known to

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release substantial amounts of metals like aluminum (Al), zinc (Zn), manganese (Mn), lead (Pb), nickel (Ni), copper (Cu), and mercury (Hg) into the environment. Additionally, volatile heavy metals such as mercury (Hg) and selenium (Se) can be released during the combustion of carbonaceous materials like coal and oil. Natural vegetation also plays a role in the cycling of heavy metals. Through processes like leaching from leaves and stems, decomposition of plant matter, and volatilization, plants can transfer heavy metals to the soil and atmosphere. These combined processes contribute to the ongoing redistribution of heavy metals within ecosystems, influencing their bioavailability and potential environmental impact.

2. **Agricultural Sources of Heavy Metals:** Inorganic and organic fertilizers, including animal dung, are the primary sources of heavy metals in agricultural soil. Various heavy metal-based insecticides and fungicides exhibit differing concentrations of Cd, Cr, Ni, Pb, and Zn, contingent upon their origins. The contamination of soil by heavy metals may also originate from irrigation water sources, including lakes, ponds, deep wells, rivers or irrigation canals.

3. **Industrial Sources of Heavy Metals:** The industrial origins of heavy metals include mining, refining, smelting, and casting activities. Contamination of soil and water bodies may occur via runoff resulting from mine waste erosion, dust produced during crude ore transport, metal corrosion, and the leaching of heavy metals into soil and groundwater. Coal combustion in power plants, petroleum burning, nuclear power facilities, and high voltage transmission lines release numerous heavy metals, including Se, B, Cd, Cu, Zn, Cs, and Ni, into the environment. Additional industrial sources encompass the processing of polymers, textiles, paper manufacturing, wood preservation, and electronics. For instance, Singrauli in Madhya Pradesh, a prominent thermal power producing location, exhibited elevated mercury levels in the hair of exposed persons.

4. **Domestic Effluents:** These wastewater discharges likely represent the predominant source of increased metal concentrations in rivers and lakes. The utilization of detergents poses a potential pollution risk, as typical household detergent products might impact water quality.

5. **Atmospheric Sources:** Both natural and anthropogenic mechanisms have been demonstrated to produce airborne particles containing metals. Subject to existing climatic conditions, these particulates may be transported by wind over extensive distances and are eventually deposited back into the

lithosphere through precipitation in the form of rain or snow. Geothermal sources, including volcanic eruptions, have resulted in considerable air pollution.

6. **Other Sources:** Additional sources of heavy metals comprise garbage incineration, landfills, and transportation (automobiles, diesel vehicles, and aircraft). The combustion of leaded gasoline has been a significant source of lead in the environment.

III. CONTAMINATION OF HEAVY METALS IN INDIA

Heavy metal contamination has been detected throughout India. Approximately 718 districts have groundwater contaminated with chromium, arsenic, cadmium and lead. Groundwater poisoned with arsenic affects significant states like Uttar Pradesh, Jharkhand, Bihar, Manipur, West Bengal, Assam and Chhattisgarh. Conversely, air pollution and contaminated agricultural fields have been documented, particularly selenium toxicity, affecting 9% of individuals in the Nawansahar and Hoshiarpur districts of Punjab. Industrialization significantly contributes to contamination in locations such as Talcher (Orissa), Ratlam (Madhya Pradesh), Vadodara (Gujarat), Ranipet (Tamil Nadu), Ganjam (Orissa), Singrauli (Madhya Pradesh), Balai (Uttar Pradesh), and Malanjkhand (Madhya Pradesh). The Ganga is contaminated with chromium, lead, copper, nickel and iron. The Ministry of Environment, Forest and Climate Change (MoEF&CC) has pinpointed 320 sites in India with a high likelihood of pollution from heavy metals (Cr, As, Pb, Hg and Cu) and pesticides. The water of the Yamuna River is polluted with heavy metals as a result of the discharge of both treated and untreated industrial and domestic effluent from various sources.

IV. TOXICITY OF HEAVY METALS

The widespread use of heavy metals in industries, agriculture, and medicine has led to environmental contamination, posing risks to human health. The severity of toxicity depends on factors like dose, exposure route, and the individual's age, gender, genetics, and nutritional status. Vulnerable groups, such as children and the elderly, are particularly at risk. *Harmful effects of some heavy metals are summarized in table 2*.

Metallic ions have a profound impact on cellular components, interacting with DNA and nuclear proteins causing DNA damage and structural alterations, which finally triggers apoptosis and carcinogenesis. Laboratory studies have demonstrated the pivotal role of ROS (reactive oxygen species) and oxidative stress in mediating the toxicity and carcinogenicity of heavy metals. Among these, arsenic, lead, cadmium, chromium and mercury are considered systemic toxicants of significant public health concern due to their ability to cause extensive damage to multiple organs, even at low concentration. Furthermore, these metals are recognized as human carcinogens, underlining their hazardous nature and the critical need for effective management and mitigation strategies.

Cadmium, chromium, arsenic, lead and mercury are major heavy metal pollutants that enter the human body through ingestion, inhalation, or skin contact. They cause a range of health issues, including, diabetes, blood abnormalities, cardiovascular diseases, neurological disorders and cancers. The effects vary based on the nature and dose of metal, as well as the duration of exposure. Both acute and chronic heavy metal toxicities show long- health impacts. Additionally, these metals can disrupt normal metabolism by interfering with essential elements like iron, calcium, and zinc, further amplifying their harmful effects.

Table 2: Harmful effects of heavy metals (Adopted from Mehrandish et al, 2019 & Balali-Mood et al.,2021)

Heavy metals	Harmful Effects
Mercury	Fatigue, anorexia, irritability and excitability, hepatotoxicity, cardiovascular disease, hypertension with renal dysfunction, and reduced sensory abilities.
Cadmium	Degenerative bone disease (*"Itai-itai"* disease), hair loss, hypertension, anemia, reproductive dysfunction and kidney issues.
Lead	Hyperactivity and delayed mental development in children. Reduced pulmonary function, fatigue, anaemia, metallic taste, loss of appetite, weight loss, migraines, and insomnia in adults.
Arsenic	Liver damage, Fatigue, migraines, GI discomfort, dermatitis, increased salivation, cardiovascular dysfunction, muscular weakness, hair and nail loss, and an elevated risk of cancer.
Chromium (Hexavalent)	Vascular damage, immune system dysfunction, birth defects, cancer, skin lesions, nervous system disorders, and gastrointestinal and kidney dysfunction.
Nickel	Potential carcinogenic effects, cardiovascular and kidney diseases, pulmonary fibrosis, and skin allergies.

Copper	Although it is necessary in small quantities, prolonged exposure can result in renal dysfunction, liver damage, and gastrointestinal distress.
Zinc	Necessary for physiological functions, but excessive consumption can result in nausea, vomiting, loss of appetite, stomach cramps, diarrhoea, and headaches.

V. TREATMENT OF HEAVY METAL TOXICITY

1. Treatment of Heavy Metal Contamination in Soil

Heavy metal-contaminated soils can be remediated using various technologies, including isolation, immobilization, toxicity reduction, physical separation, and extraction. Isolation involves using caps, membranes, or barriers to contain contaminants. Immobilization reduces metal mobility by altering soil properties. Toxicity reduction converts toxic metals into less harmful forms through chemical or biological means. Physical separation mechanically removes contaminated soil, while extraction uses chemicals, heat, or electrolysis to remove metals. The choice of method depends on the contaminant type and site conditions.

2. Treatment of Heavy Metal Poisoning in Human

The first step in treating heavy metal poisoning is to eliminate the source of exposure and ensure the patient is no longer in contact with it. Treatment primarily involves supportive care and monitoring of vital organs like the kidneys, liver, lungs, and heart. Chelating agents are commonly used to bind heavy metals, making them harmless and facilitating their removal from the body. Some plants with natural chelating properties can reduce metal absorption and promote toxin elimination through feces. While herbal remedies may offer additional support, chelation therapy can also remove essential metals, so vitamin and mineral supplements are often provided to restore balance.

Metallothioneins are proteins that bind heavy metals, aiding in metal detoxification and oxidative stress protection by reducing their absorption and promoting detoxification.

For example:
- Food fibers from cereals and fruits can reduce enterohepatic recirculation.
- Natural polymers like alginate, *Chlorella*, and citrus pectin act as metal absorbents.

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- Sulfur-rich foods, including garlic, onion, and broccoli, enhance heavy metal removal.
- Cilantro (*Coriandrum sativum*) is also valued for its detoxifying properties.

Medicinal herbs that are found to be effective in treating heavy metal poisoning include cilantro (*Coriandrum sativum),* ginkgo (*Ginkgo biloba*), garlic (*Allium sativum*), milk thistle (*Silybum marianum*), turmeric (*Curcuma longa*). Additionally, phytochelatins, triphala, herbal fibers, and green algae are known for their detoxifying properties and can support the removal of heavy metals from the body.

Recommendations of TERI: TERI (The Energy and Resource Institute) has recommended measures to mitigate heavy metal contamination in India:

- Develop zonal maps to identify high-risk areas for public health protection.
- Conduct priority-based biomarker assessments in populations.
- Regularly monitor contaminants in soil, water, crops, and marine produce.
- Establish feedback systems for real-time environmental data to aid policymaking.
- Formulate provisional standards for heavy metal concentrations in irrigation water, soil, aquaculture ponds, and crops.
- Encourage customized agricultural practices to reduce contamination pathways.
- Enhance analytical capacity through training and laboratory networks.
- Regulatory measures to prevent contamination of heavy metals in India

The Drugs and Cosmetics Rules (1945) forbids cosmetics that contain mercury compounds. The Bureau of Indian Standards (BIS) has established permissible limits for heavy metals in cosmetics, specifically arsenic at 2 ppm and lead at 20 ppm. The maximum permissible concentrations of cadmium and lead in milk are 10 and 20 ppm, respectively.

The **Central Pollution Control Board (CPCB)** has set permissible limits for heavy metals in effluents released into inland surface water: 0.1 mg/L for lead, 2.0 mg/L for cadmium, 0.2 mg/L for arsenic, 0.01 mg/L for mercury, 0.1 mg/L for chromium (VI), and 0.05 mg/L for selenium. However, most of permissible limits for heavy metals in land discharge for irrigation are unspecified.

VI. CONCLUSIONS

Metals such as iron, chromium, aluminium, and zinc are crucial for numerous physiological and biochemical processes in plants and animals; yet, they can become hazardous if consumed in excessive amount. Heavy metals, including mercury, arsenic, lead, cadmium, and uranium, have no substantial metabolic function in the human body and are therefore poisonous. Exposure to high concentrations in short time can lead to acute toxicity and observable health issues, whereas equivalent effects from long-term exposure to trace levels are not immediately apparent and are more challenging to manage. Rapid industrialization and escalating anthropogenic activities in a developing nation like India have produced significant environmental issues, leading to dire and perhaps lethal consequences of heavy metal poisoning. Several scientific evidence indicates an increased concern over the health impacts associated with these metals; hence, the present circumstances need the identification of environmental health concerns in polluted regions of India. Consequently, the development and implementation of mitigation strategies, accompanied by relevant policies, are urgently required.

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THE IMPACT OF CLIMATE CHANGE AND ITS EFFECTS ON AQUATIC ECOSYSTEMS

Abstract

Inland surface water, seawater, and groundwater are all considered to be part of the aquatic ecosystem. which have water insects, microorganisms, phytoplankton, and zooplankton. Aquatic insects do not constitute a separate taxonomical unit within the class Insecta because they are descended from a variety of terrestrial predecessors that have secondarily invaded aquatic sites. Certain insect orders and their life stages are found in aquatic in e.g., mayflies, stoneflies, dragonflies, caddisflies, megalopterans). The aquatic insects, serve as scavengers, bioindicators, and decomposers in the food chain and food webs of any aquatic ecosystem, is covered in this chapter. The climate system has recently been regulated at many levels and is thought to affect all ecosystems worldwide. Of all the systems, freshwater systems are the most susceptible.

As a result, aquatic life suffers from a loss of diversity, a reduction in the size of their distribution, and deteriorating habitat quality. Impacts are expected to be accelerated by the combined effects of direct climate change and the growing anthropogenic pressure on freshwater resources. There is a significant research and adaptation vacuum shown by the scarcity of published work on climate change and its expected regional effects on aquatic insects. There includes

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discussion of the ecological issues and difficulties as well as adaptive measures to lessen the effects of climate interferences on aquatic systems and insect diversity. Because species and the physical characteristics of the aquatic environment are inextricably linked, freshwater ecosystems are especially vulnerable to climate change. The biological characteristics and ecological preferences of mayflies, stoneflies, and caddisflies dictate their susceptibility to climate change, making them important markers of the condition of freshwater ecosystems. The biological characteristics and ecological preferences of mayflies, stoneflies, and caddisflies dictate their susceptibility to climate change, making them important markers of the condition of freshwater ecosystems.

Keywords: Inland, Climate change, Aquatic ecosystem, Aquatic Insects, Bio indicators, Ephemeroptera, Plecoptera, Trichoptera, Decomposers, Scavengers.

I. INTRODUCTION

Climate change is one of the most important factors for environmental issues of the 21st century, affecting ecosystems across the globe (Adger et al. 2005; Leal Filho et al. 2021; Feliciano et al. 2022). As the planet continues to warm due to human-induced greenhouse gas emissions, ecosystems around the globe are experiencing profound and far-reaching changes. Among the most vulnerable of these ecosystems are aquatic environments, including oceans, rivers, lakes, wetlands, and estuaries. Aquatic ecosystems are not only essential for the survival of countless species but also play a critical role in regulating the planet's climate, supporting biodiversity, and providing invaluable resources for human life (Ashok, 2015; Kumar and Verma, 2017; Arya, 2021).

In recent decades, it has become increasingly clear that the health and stability of aquatic ecosystems are being severely disrupted by the consequences of climate change. Rising global temperatures, changing precipitation patterns, ocean acidification, and the melting of polar ice caps are just a few of the significant drivers of these changes (Huang et al., 2021). These environmental shifts are leading to a wide array of impacts on aquatic ecosystems, ranging from altered species distributions and changes in water quality to the loss of biodiversity and the disruption of food webs. The implications of these changes are profound, not only for the organisms that inhabit these ecosystems but also for the millions of people who depend on aquatic environments for food, livelihoods, and cultural practices.

This introduction will explore the complex relationship between climate change and aquatic ecosystems, providing a foundational understanding of how global warming and other climate-related phenomena are affecting the health and functionality of these vital habitats. By examining the science behind climate change and its specific effects on aquatic environments, this discussion will focus on the urgency of addressing the challenges face by a warming world and the importance of implementing strategies for conservation and adaptation.

As environmental condition and their impacts of climate change continue to unfold, understanding the ways in which aquatic ecosystems are being affected is critical to ensuring the sustainability of these ecosystems and the species—both aquatic and terrestrial—that rely on them. Whether through increasing in temperature globally, sea level rise, ocean acidification, or extreme weather events, the ripple effects of climate change on aquatic ecosystems are diverse and interconnected, creating a complex and multifaceted challenge for scientists, policymakers, and environmentalists alike.

In the present articlewe will delve deeper into the various dimensions of climate change's impact on aquatic ecosystems, discussing the specific drivers of change, the consequences for biodiversity and change is one of the most pressing environmental issues of the 21st century, affecting ecosystems across the globe. As the planet continues to warm due to human-induced greenhouse gas emissions, ecosystems around the globe are experiencing profound and far-reaching changes.

Climate warming responsible in rising sea levels, a strident decline in biodiversity, and ecological degradation that is significantly impacting agriculture and forestry (Alhamid et al., 2022). China, is the one of the major greenhouse gas emissions from agricultural production and processing of products (Zhang et al., 2022).Among the most vulnerable of these ecosystems are aquatic environments, including oceans, rivers, lakes, wetlands, and estuaries. Aquatic ecosystems are not only essential for the survival of countless species but also play a critical role in regulating the planet's climate, supporting biodiversity, and providing invaluable resources for human life.

In recent decades, it has become increasingly clear that the health and stability of aquatic ecosystems are being severely disrupted by the consequences of climate change. Rising global temperatures, changing or disrupting precipitation in different geographical, ocean acidification, and the melting of polar ice caps are just a few of the significant drivers of these changes (Huang et al., 2021). These environmental shifts are leading to a wide array of impacts on aquatic ecosystems, ranging from altered species distributions and changes in water quality to the loss of biodiversity and the disruption of food webs. The implications of these changes are profound, not only for the organisms that inhabit these ecosystems but also for the millions of people who depend on aquatic environments for food, livelihoods, and cultural practices (Efe and Bemigho, 2021).

Now its most important to explore the complex relationship between climate change and aquatic ecosystems, providing a foundational understanding of how global warming and other climate-related phenomena are affecting the health and functionality of these vital habitats. By examining the science behind climate change and its specific effects on aquatic environments, this discussion will highlight the urgency of addressing the challenges posed by a warming world and the importance of implementing strategies for conservation and adaptation.

Impact of climate change continue to unfold, understanding the ways in which aquatic ecosystems are being affected is critical to ensuring the sustainability of these ecosystems and the species—both aquatic and terrestrial—that rely on them. Whether through changes in temperature, sea level rise, ocean acidification, or extreme weather conditions, the ripple effects of climate change on aquatic ecosystems are diverse and interconnected, creating a complex and multifaceted challenge for scientists, policymakers, and environmentalists alike. The following sections will delve deeper into the various dimensions of climate change’s impact on aquatic ecosystems, discussing the specific drivers of change, the consequences for biodiversity and ecosystem services, and the potential pathways for mitigating these impacts. Through this exploration, we can gain a more comprehensive understanding of the stakes involved and the actions needed to protect the world's aquatic ecosystems from the accelerating

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threat of climate change. While much attention is given to terrestrial ecosystems, aquatic ecosystems—including oceans, lakes, rivers, and wetlands—are equally vulnerable to the changing climate. Rising temperatures, ocean acidification, altered precipitation patterns, and extreme weather events have profound consequences for marine and freshwater life. These changes disrupt food chains, impact biodiversity, and threaten human livelihoods that depend on water resources.

Considering to the above discussing situations here weexplores how climate change is affecting aquatic ecosystems, its causes and consequences, and potential mitigation strategies to safeguard water environments and their rich biodiversity.

1. **Understanding Climate Change and Its Drivers:** Climate change can be defined asl the long-term changes in temperature of earth, rain in different regions, wind patterns, and other elements of the Earth’s climate system.Temperature of earth surface are increasing by 1.5 to 5.8^{0}C by 2100 (Houghton et al., 2001). Climate change represents an additional, significant menace to aquatic ecosystems (fresh water and marine water), and that will interact in complex ways with existing Anthropogenic-caused stresses (Carpenter et al., 1992; Lake et al., 2000). It is majorly driven by Anthropogenic activities, including:
   - **Greenhouse Gases (GHGs):** As like Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from fossil fuels and natural resources, deforestation, and industrial processes that trap heat in the Earth's atmosphere, causing global warming.
   - **Deforestation and Land-Use Changes:** Reduced tree cover limits the absorption of CO_2, accelerating climate change.
   - **Industrialization and Urbanization:** Increased energy consumption leads to higher emissions.
   - **Agriculture and Livestock Farming:** Methane from cattle and fertilizers contribute to greenhouse gas buildup.

   These human-induced activities, combined with natural processes such as volcanic eruptions in different areas and ocean currents, influence climate patterns worldwide.

2. **Key Climate Change Effects on Aquatic Ecosystems:** Aquatic ecosystems are highly sensitive to environmental changes (Alhamid et al., 2022).Climate change is reshaping aquatic ecosystems through a variety of mechanisms, with temperature rise being one of the most significant factors. Globally the

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earth temperatures have increased by approximately 1.1°C since the late 19th century, with many regions experiencing even greater warming (Houghton et al., 2001). This temperature increase, though seemingly modest, has profound consequences for water bodies across the globe. Warm water holds less oxygen, creating conditions that are often inhospitable for aquatic life. Many species of fish, invertebrates, and microorganisms are highly sensitive to changes in temperature and are being forced to either migrate to more suitable environments or face the risk of population decline or extinction.

Another major climate change driver-affecting aquatic ecosystems is the alteration of precipitation patterns. As global temperatures rise, the hydrological cycle intensifies, leading to more extreme weather events such as heavy rainfall, flooding, and droughts. These changes have a direct impact on freshwater ecosystems, influencing water availability, river flow patterns, and the overall health of watersheds. Floods can introduce excess nutrients and pollutants into aquatic systems, leading to eutrophication and harmful algal blooms, while droughts can reduce water levels, leading to habitat loss and increased competition for resources.

The prominent impacts of climate change on aquatic environments include:

1. **Rising Water Temperatures**
    - Warmer water temperatures can disrupt aquatic ecosystems by affecting species metabolism, reproduction, and survival.
    - Many marine and freshwater organisms, such as corals and fish, have specific temperature tolerances.
    - Coral bleaching occurs when higher temperatures cause corals to expel their symbiotic algae, leading to their death.
    - Warmer waters accelerate the spread of invasive species and harmful algal blooms, disrupting food chains.

2. **Ocean Acidification**

While the rise in atmospheric carbon dioxide (CO2) is primarily associated with global warming, it also plays a significant role in another process that is wreaking havoc on aquatic ecosystems: ocean acidification (Gattuso et al., 1998; Kleypas et al., 1999). Oceans act as a major carbon sink, absorbing roughly a quarter of the CO2 emitted by human activities. As CO2 dissolves in seawater, it reacts to form carbonic acid, which lowers the pH of the water. Since the beginning of the Industrial Revolution, the average pH of ocean surface waters has decreased by about 0.1 units, representing a 30% increase in acidity.

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Ocean acidification has particularly devastating effects on marine organisms that rely on calcium carbonate to build their shells and skeletons, such as corals, mollusks, and some species of plankton. As acidity increases, these organisms struggle to maintain their structural integrity, leading to weakened populations and diminished biodiversity. Coral reefs, often referred to as the "rainforests of the sea" due to their incredible biodiversity, are especially vulnerable to the twin threats of warming waters and acidification. Coral bleaching, a phenomenon in which corals expel the symbiotic algae that provide them with nutrients and color, is becoming more frequent and severe as ocean temperatures rise. When combined with the effects of acidification, this can lead to widespread coral die-offs and the collapse of reef ecosystems (Gattuso et al., 1998; Kleypas et al., 1999).

Rising Sea Levels: Drowning Coastal Habitats: As global temperatures rise, the polar ice caps and glaciers are melting at an unprecedented rate, contributing to sea level rise. Additionally, warmer ocean temperatures cause thermal expansion, further increasing the volume of seawater. Over the past century, global sea levels have risen by about 20 centimetres, and the rate of increase is accelerating. Projections suggest that sea levels could rise by as much as 1 to 2 meters by the end of the century, depending on future greenhouse gas emissions and ice sheet dynamics.

The impacts of rising sea levels on coastal ecosystems are multifaceted. Coastal wetlands, mangroves, and estuaries are particularly at risk, as these habitats are often located at the interface between land and sea. As sea levels rise, these habitats may become inundated, leading to the loss of critical breeding grounds for fish, birds, and other wildlife. Coastal erosion, saltwater intrusion into freshwater systems, and the displacement of human populations are additional consequences of sea level rise, further compounding the challenges faced by coastal ecosystems.

- The ocean absorbs about 30% of atmospheric CO_2, leading to increased acidity.
- Acidification affects marine organisms, particularly those with calcium carbonate shells (e.g., corals, mollusks, and some plankton species).
- Weakening of shells makes these organisms more vulnerable to predation and decreases their survival rates.
- Disruption in the food web as many small organisms are foundational to marine biodiversity.

3. Altered Precipitation and Hydrological Cycles

- Climate change intensifies the water cycle, leading to more severe droughts and heavy rainfall events.
- Changes in rainfall impact freshwater ecosystems by altering water flow, reducing water levels, and affecting species dependent on stable water conditions.
- Flooding and excessive runoff wash pollutants, sediments, and nutrients into rivers and lakes, deteriorating water quality.

4. Melting Glaciers and Rising Sea Levels

- Glacial melt contributes to rising sea levels, affecting coastal and estuarine ecosystems.
- Rising sea levels lead to saltwater intrusion into freshwater systems, affecting drinking water supplies and freshwater biodiversity.
- Coastal habitats, such as mangroves and salt marshes, are at risk of submersion, leading to habitat loss.

5. Hypoxia and Dead Zones

- Warmer waters hold less dissolved oxygen, creating hypoxic (low-oxygen) zones in oceans and lakes.
- Excessive nutrient runoff from agriculture combined with warming temperatures increases dead zones, areas where aquatic life cannot survive.
- Fish kills and loss of biodiversity result from oxygen depletion

II. IMPACT ON MARINE ECOSYSTEMS

Aquatic ecosystems support a remarkable diversity of life, ranging from microscopic phytoplankton to large marine mammals. However, the impacts of climate change are causing significant disruptions to the intricate relationships that exist within these ecosystems (Prakash and Srivastava, 2019; Mandal and Singh, 2020; Arya, 2021). As water temperatures rise and ecosystems are altered, species that are unable to adapt quickly enough may face extinction, leading to a loss of biodiversity. In particular, species that have narrow temperature ranges or specific habitat requirements, such as cold-water fish species, are especially vulnerable to the effects of climate change. Changes in species distributions are already being observed in many aquatic ecosystems. For example, as ocean temperatures warm, fish species are migrating to higher latitudes in search of cooler waters. This can lead to shifts in the composition of marine communities, with potential consequences for food webs and ecosystem functioning. Predator-prey relationships may be disrupted, and the availability of key species that serve as food sources for other organisms, including humans, may be reduced.

1. Coral Reefs in Crisis

Coral reefs, often referred to as the "rainforests of the sea," are highly vulnerable to climate change (Bryant et al., 1998). Coral bleaching events, caused by increased sea temperatures, have devastated reefs worldwide. The loss of coral reefs threatens biodiversity and the livelihoods of millions who depend on reef-based fisheries and tourism.

2. Impact on Fish Populations

- Changes in ocean temperatures and currents alter fish migration patterns, reproduction cycles, and availability of food sources.
- Some fish species may shift to cooler waters, disrupting traditional fishing industries.
- Declining fish populations due to ocean acidification and habitat destruction affect global seafood supply and economies reliant on fisheries.

3. Disruption of Ocean Currents

- Climate change is altering major ocean currents, such as the Atlantic Meridional Overturning Circulation (AMOC).
- Slowing currents impact global climate patterns, fisheries, and the distribution of marine life.
- Disruptions in currents can lead to extreme weather events, including hurricanes and prolonged droughts.

III. IMPACT ON FRESHWATER ECOSYSTEMS

Freshwater ecosystems, which include lakes, rivers, wetlands, and streams, are among the most sensitive to the impacts of climate change. Unlike oceans, freshwater systems have more limited buffering capacities, making them more susceptible to changes in temperature, precipitation, and other climate-related factors. One of the most visible effects of climate change on freshwater systems is the alteration of water availability. In some regions, reduced snowfall and earlier snowmelt are leading to lower water levels in rivers and lakes, while in others, increased precipitation is causing more frequent and severe flooding events (Anonymous, 2007).

These changes in water availability have cascading effects on freshwater ecosystems and the species that depend on them. For instance, changes in river flow patterns can affect the migration and spawning of fish species such as salmon, while reduced water levels in lakes and wetlands can lead to habitat loss for amphibians, waterfowl, and other aquatic organisms. Additionally, as water temperatures increase, freshwater systems are becoming more prone to the development of harmful algal blooms, which can produce toxins that are harmful to both aquatic life and humans.

1. Changes in River and Lake Ecosystems

- Higher temperatures lead to increased evaporation rates, reducing water availability in lakes and rivers.
- Reduced river flows affect fish spawning and migration, disrupting species like salmon that rely on seasonal water flows.

2. Impact on Wetlands

- Wetlands serve as important carbon sinks and biodiversity hotspots.
- Climate change-induced droughts and rising sea levels threaten wetland ecosystems.
- Loss of wetlands reduces water filtration, increases flood risks, and affects bird and amphibian populations.

3. Increased Spread of Waterborne Diseases

- Warmer water temperatures create favourable conditions for pathogens and harmful bacteria.
- Diseases such as cholera and toxic algal blooms are more prevalent in warmer, polluted waters.
- Water quality degradation affects human health and drinking water safety.

IV. SOCIOECONOMIC CONSEQUENCES OF AQUATIC ECOSYSTEM DISRUPTIONS

Aquatic ecosystems are not only important for the species that inhabit them but also for the millions of people who rely on them for food, livelihoods, and cultural practices. Fisheries, both marine and freshwater, provide a critical source of protein for over 3 billion people worldwide, and many coastal and indigenous communities depend on fishing as their primary economic activity. However, climate change is threatening the sustainability of global fisheries, with potential consequences for food security and human well-being.

As ocean temperatures rise and species distributions shift, fish stocks are becoming increasingly unpredictable, making it more difficult for fishers to sustain their livelihoods. Overfishing, habitat degradation, and pollution exacerbate these challenges, further stressing fish populations. In some regions, the effects of climate change on fisheries are already being felt, with declining catches and changing species compositions leading to economic losses and increased competition for resources.

1. Threats to Fisheries and Food Security

- Millions of people worldwide rely on fish as a primary protein source.
- Declining fish populations due to climate change threaten global food security.
- Coastal communities dependent on fishing face economic instability as fish stocks decline.

2. Loss of Livelihoods in Coastal Communities

- Climate change affects industries such as tourism, fishing, and aquaculture.
- Coral reef loss impacts diving and snorkelling industries, reducing tourism revenue.
- Fishermen and seafood-dependent industries face economic hardship due to changing fish populations.

3. Increased Natural Disasters and Infrastructure Damage

- Rising sea levels and extreme weather events increase coastal erosion and flooding.

- Damage to infrastructure, such as ports and water treatment plants, leads to costly repairs.
- Small island nations are particularly vulnerable to climate-induced displacement.

V. MITIGATION AND ADAPTATION STRATEGIES

1. Reducing Greenhouse Gas Emissions

- Transitioning to renewable energy sources (solar, wind, hydro) reduces dependence on fossil fuels.
- Implementing carbon capture technologies and afforestation projects can help offset emissions.

2. Sustainable Fisheries and Marine Conservation

- Establishing marine protected areas (MPAs) to safeguard biodiversity.
- Promoting sustainable fishing practices to prevent overfishing.
- Supporting aquaculture innovations to reduce pressure on wild fish stocks.

3. Water Resource Management

- Implementing better water conservation practices and policies.
- Protecting and restoring wetlands, mangroves, and natural water buffers to enhance resilience.
- Improving wastewater treatment to reduce pollution and prevent algal blooms.

4. Global Climate Action and Policy Initiatives

- Strengthening international agreements like the Paris Agreement to limit global warming.
- Enhancing climate adaptation funding for vulnerable regions.
- Promoting public awareness and community-based conservation efforts.

VI. CONCLUSION

Climate change poses significant threats to aquatic ecosystems, impacting marine and freshwater biodiversity, food security, and human livelihoods.

Rising water temperatures, ocean acidification, altered precipitation patterns, and habitat destruction are driving shifts in aquatic environments. Urgent action is needed to reduce greenhouse gas emissions, promote sustainable resource management, and implement conservation efforts to protect these fragile ecosystems. While the challenges are immense, proactive strategies and global cooperation can help mitigate the impacts of climate change on aquatic ecosystems, ensuring a healthier future for both marine life and humanity.

The impacts of climate change on aquatic ecosystems are profound and multifaceted, affecting everything from species distributions and water quality to the livelihoods of human communities. As global temperatures continue to rise, the need for concerted action to protect these ecosystems has never been more urgent. Efforts to mitigate the effects of climate change, such as reducing greenhouse gas emissions, protecting critical habitats, and promoting sustainable fisheries management, are essential for ensuring the long-term health and resilience of aquatic ecosystems.

In addition to mitigation efforts, adaptation strategies will also play a crucial role in helping aquatic ecosystems and the species that depend on them cope with the changing climate. Restoration of wetlands, coral reefs, and mangroves, for example, can help enhance the resilience of coastal ecosystems

Conflict of interest
There is no any conflict of interest.

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DETECTION OF ORAL CANCER BY FLUORESCENCE BASED PORTABLE DEVICE AND CLASSIFICATION OF THE CANCEROUS STAGES BY MACHINE LEARNING METHODS

Abstract

In the present study, we utilized a fluorescence based portable device for the detection of oral cancer as well as used the machine learning methods for the classification of cancerous stages. In house build device consists of optical components, laser, spectrometer, and other accessories. Laser light (λ_{exc} = 405 nm) irradiated onto the oral cavity tissue excite the two flurophores namely FAD (λ_{emi} ≈ 500nm) and Porphyrin (λ_{emi} ≈ 634 nm). Fluorescence spectra were recorded by the spectrometer in the spectral range of 450 to 750 nm. We observed the significant rise in the porphyrin fluorescence in OSCC and dysplastic patients than the healthy participants. Data analysis was carried out by machine learning methods such as principle component analysis (PCA), linear & quadratic discriminant analysis (LDA & QDA), and receiver operating characteristic (ROC) analysis. The overall classification efficacy of classifiers was more than 96%. PCA based QDA classifier was able to discern among the groups with slightly higher values of accuracies than the LDA. Results reveal that in-house developed device coupled with the QDA classifier would be an elegant

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tool for the identification of oral cancer at various stages.

Keywolds: Oral lesions, fluorophores, fluorescence spectroscopy, machine learning methods

I. INTRODUCTION

Oral cancer takes place is the various anatomical sites (tongue, lip, buccal mucosa, gingiva etc.) of oral cavity. The key factors (≈80%) responsible for oral cancer are excessive consumption of unhealthy products such as tobacco, pan-masala, smoking (cigarate and bidi) and alcohol. Globally, it is six most cancer, However, in India it is ranked no.1 among males and third most among females. To detect oral cancer, several conventional techniques are utilized by the clinicians. Visual inspection is first step towards this goal. Apart from this, techniques such as brush biopsy, toluidine blue, and tissue biopsy have been adopted by clinicians. But among conventional techniques, tissue biopsy with histopathology is well established screening procedure or gold standard for the oral cancer detection. Though, histopathology is the authentic tool but its invasive characteristics make it incompetent. Also the chosen area for the biopsy from a patient is appropriate or not, makes patients to undergo for quite a few biopsies. Research studies presents that a five-year survival rate after the treatment is indigent (~45%) and not improved in last few decades. The poor survivability is due to delay in diagnosis and absence of early symptoms [1-2]. It is therefore requirement of devices which to be non-invasive, sensitive, fast in detection, and user friendly.

Optical devices (spectroscopic and imaging) such as fluorescence, Raman, life-time and diffuse reflectance can detect oral lesions at early stage as well as non-invasively. Among the optical devices, fluorescence based devices have been adequately utilized by the research groups for in-vivo testing of oral cancer [3-14]. A biological tissue consists of absorbers, scatters, and fluorophores. The key fluorophores in visible region are tryptophan, collagen, elastin, NADH, FAD, porphyrin etc. These fluorophores have a certain excitation and emission wavelengths at which they yield maximum emission and absorption. It is well known that flurophore concentration varies with the progress of cancer and these changes could be seen in the fluorescence signal. Data analysis is also an important part for such clinical studies to predict/identify the various stages of cancer. For data analysis, various multivariate analysis methods such as PCA, LDA, SVM, neural network, are adopted by the research groups/scientist.

In this paragraph, we have included a few key findings for in-vivo detection of oral cancer using the spectroscopic devices and machine learning methods by the research groups. In the findings, Diana C.G. de Veld et al. group executed a detailed study for in-vivo identification of oral cancer. In their first work, they performed an anatomy-based study on control (healthy) group only and observed the significant changes in the fluorescence intensity values among the anatomical sites of oral cavity [6]. In other work, they performed measurements on three groups i.e., benign, dysplastic, malignant lesions using the auto-fluorescence spectroscopy (λ_{exc} = 350-450 nm) and differentiated the malignant lesions from healthy volunteers with ROC-AUC value of 0.97 [7]. A fluorescence-based handheld device utilized by the Lane et al. group for the visualization of oral cavity lesions, classified the lesions with the sensitivity of 98% and specificity of 100% [8]. Nazeer et al. group concluded that fluorescence spectroscopy along with the PCA-LDA based multivariate analysis methods could discriminate groups such as habitués, non-habitués, and leukoplakia with sensitivity and specificity values of 60 to 100% and 76 to 100% respectively [9]. Our group also conducted a clinical study for the identification of oral cancer using fluorescence based portable device. Classification accomplished by the machine learning methods namely PCA, SVM, ROC, and Mahalanobis distance models had manifested excellent results [10-12].

II. MATERIALS AND METHODS

Measurement Technique: We had built a device based on the fluorescence for in-vivo detection on patients (OSCC & Dysplastic) and healthy volunteers. Optics of the device can be understood by the ray diagram (Fig. 1(a)). For the measurement, device was installed in the Hallet Hospital also well known as Lala Lajpat Rai Hospital Kanpur, UP, India. A photograph of the device with the all the required components is shown in Fig. 1(b). Laser light (λ_{exc} = 405 nm) was illuminated on the lateral boarder of tongue (LBT) of the oral cavity and fluorescence signal were recorded by the UV-visible spectrometer (spectral response 200-1100 nm). An integration time of 3s was taken which was ample to get the fluorescence signal from all the sites of oral mucosa. Spectra-suit software was used to visualize the spectra and the interfacing between the spectrometer and laptop was done using a USB cable. After the completion of the measurements from a patient, cap was disposed.

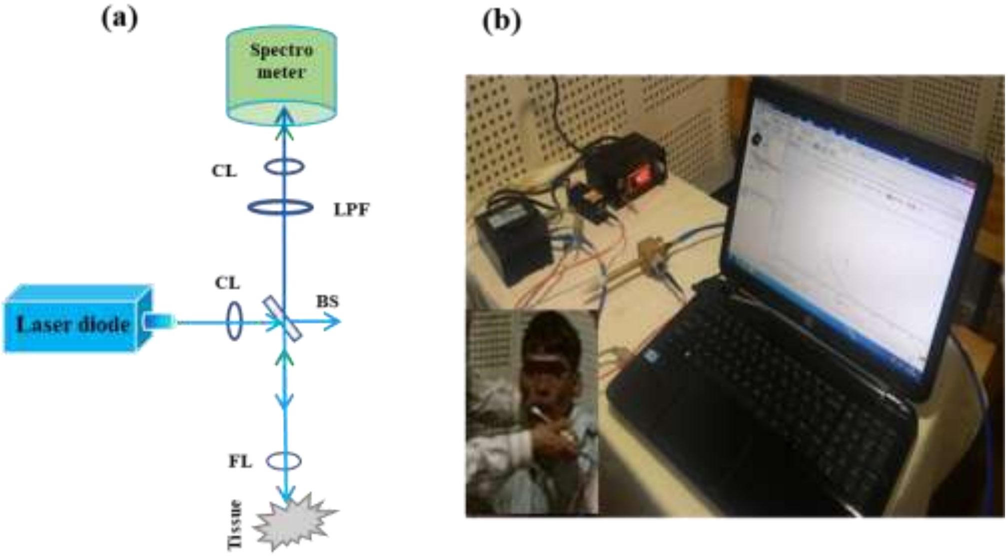

Figure 1: (a) Ray diagram (b) Photograph of the device with all accessories required to execute measurements

Data Collection: Fluorescence data was acquired from 55 LBT sites of 20 oral squamous cell carcinoma (OSCC) patients, 49 LBT sites of 18 dysplastic (precaceros) patients, and of 60 LBT sites of 36 healthy volunteers by the portable device. Mean age of all the three groups (OSCC, dysplastic, and normal) with the standard deviation was 47 ± 12, 39 ± 8, and 36 ± 7 respectively.

Follow-up of Ethical Approval: Ethical approval with the IEC communication number IITK/IEC/2015-16/2/10 was obtained to conduct the research work. This approval was approved by the committee members of IIT Kanpur and GSVM Medical College of UP, India.

Analysis Methods (PCA, LDA, and QDA): To analyze the data, we employed principal component analysis (PCA), linear discriminant analysis (LDA), Quadratic discriminant analysis (QDA) and ROC tools [14-15]. PCA on the data set was applied to reduce the dimension without the loss of essential information. It could be simply executed by computing the eigen vectors also called principal components. First five eigen values captures the total variance of ≥ 96%. PC scores corresponding to these five eigen values were computed and loaded for further use. In LDA classification, it is assumed that the data for each class have Gaussian (normal) distribution and the identical correlation matrix (common correlation matrix). LDA finds the best linear decision boundary. However in QDA, it is assumed that data is normally distributed but the correlation matrix for each class is not equal. The applicability of QDA is best when the classes have distinct variance or the decision boundary is not linear.

III. RESULTS

Averaged spectra of OSCC, dysplastic, and control groups at λ_{exc} = 405 nm is shown in the Fig. 2(a). Florescence Spectra are recoded from the lateral boarder of tongue (LBT) of the oral cavity in the spectral range of 450 to 750 nm. Averaged spectra consists of 55 tissue sites of 20 OSCC patient, 49 tissue sites of 18 dysplastic patient, and 60 tissue sites of 36 control group. In the spectra, presence of FAD and porphyrine bands at 500 nm and at 634, 676, 689, and 703 nm can be seen. Peak intensity values of porphyrin bands (634 nm) with the SD values for OSCC, dysplastic, and normal groups are 5450 ± 4510, 1650 ± 1300, and 447 ± 187 respectively. It can be seen that the difference in the peak values are significant. It can also be seen in the Fig. 2(a) that intensity of porphyrin band in OSCC patients is slightly prominent than that of FAD band. In the dysplastic patients, it is lesser than the porphyrin band intensity. However, in healthy volunteers, intensity of porphyrin band is insignificant. A typical spectrum depicted in Fig. 2(b), show that FAD band is dominant in OSCC patient than the porphyrin band. In dysplastic patient, porphyrin band intensity is slightly higher than the FAD band intensity. However, like the averaged spectra of healthy volunteers, intensity of porphyrin band is insignificant in the typical spectra too. But the presence of week porphyrn bands in healthy volunteers was noticed in almost all the volunteers.

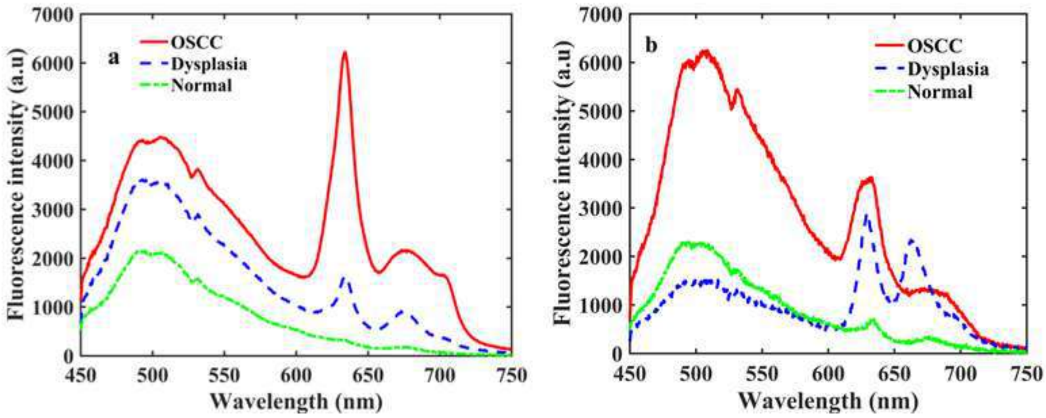

Figure 2: Spectra of OSCC, dysplastic, and normal groups at excitation wavelength of 405 nm (a) averaged (b) typical

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IV. DISCUSSION

Incremennt in the fluorescence intensities of porphyin bands with the advancement of oral mucosal lesions indicates that concentraion of porphyrin have risen, which was noticed in the majorty of the fluorescence spectra. But the spectral pattern of OSCC and dysplastic patients had also shown that it was not always true to be higher intensities of porphyrin band (634 nnm) over the FAD band (500 nm) in all the cases. Thus, analyzing the data with a specific biomarkers (($I_{porphyrin}/I_{FAD}$)) would not be an approprate procedure. However, investigating the data with the selection of entire spectral range might be a better choice. To enhance the diagnostic efficay, we selected the entire fluorescence spectra for the data analysis. Feature extraction was executed by employing the PCA on the original data which have dimension of 700 and first five PC scores consist the variance more than 96% was taken for further analysis. In the first 5 PCs, first two PCs consist of 91% variance. It signify that the key information's are lies within the first few PCs. Prior to apply the LDA and QDA methods on the PC scores; PC scores are categorized into the two sets i.e., training set and testing set. We have chosen 70 percent data for training and 30 percent data for testing. Scatter data plots or boundaries plots of LDA and QDA on first two PC scores are shown in Fig.3, and Fig.4 respectively.

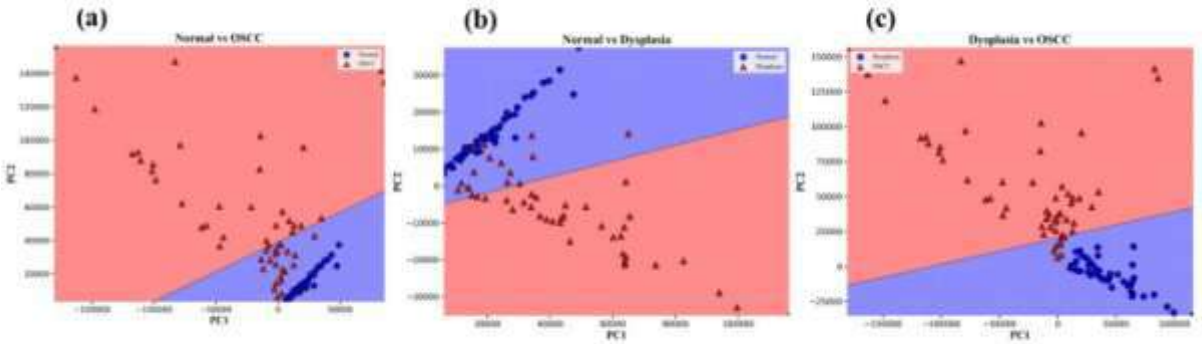

Figure 3: LDA boundaries plots for among the three groups

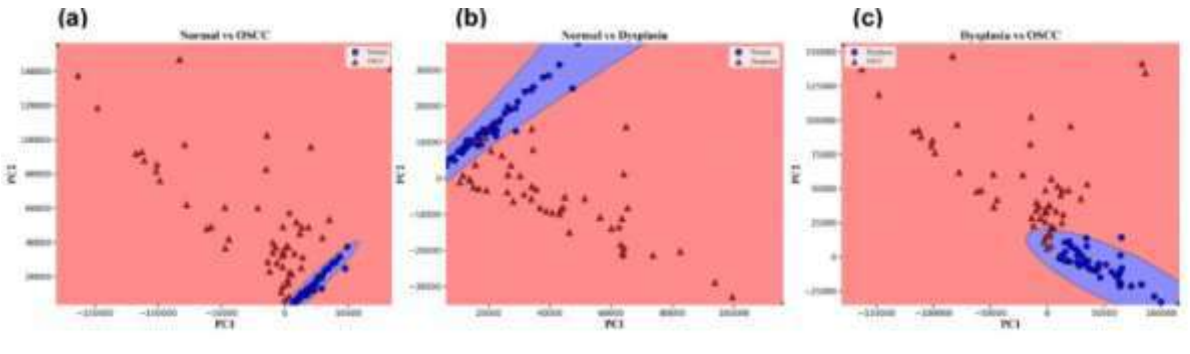

Figure 4: QDA boundaries plots for among the three groups

It can be cleary seen in the above scatter plots that there is overlap of the data points. Among few groups, it is signfcant higher and and in few it is approprate. It reveals that analyzing the data on only first two PC scores (PC1 & PC2) is not a right approach. We therefore selected first 5 PC scores and applied all these algorthims one by one. In testing data of Normal vs. OSCC, we obtained sensitivities of 82.35%, 100% with the overall accuracies of 91.42% and 97.14% for the LDA and QDA respectively. In the testing data of Normal vs. Dysplasia, we obtained senstivities of 75%, 100% with the overall accuracies of 87.87%, 100% respectively for the respective classifiers. However, in the testing data of Dysplasia vs. OSCC, senstivities 88.23%, 100% and accuracies of 93.75% and 100% were achieved. Results indicate that QDA was able to distingush with slightly greater values of sensitivities or accuracies. ROC employed on randomly chosen data sets of LDA and QDA had not exibited a significant change in the senstivity and specficty values. AUC values were significantly high (AUC = 1) for both the data sets (LDA and QDA). However in differentiating Dysplasia Vs OSCC, it was higher for QDA (AUC =.99), which proves that QDA is slightly better machine learning tool than the LDA.

V. CONCLUSION

A clinical study was accomplished here to detect and discriminate the oral cancer using the portable device and multivariate methods (PCA, LDA and QDA). Measurements were performed on three groups i.e. OSCC patients, dysplastic patients, and healthy volunteers and the fluorescence spectra were recorded in the spectral range of 450 to 750 nm. In the spectra, two key bands near 500 nm and at 634 nm along with very few trivial bands at 676, 689, and 703 nm were seen. These bands attribute to FAD and porphyrin respectively. Intensity of porphyrin bands were found less than the FAD bands in the control group. The intensity of porphyrin bands in more than 80% OSCC patients was larger or comparable to FAD bands. Nevertheless, in dysplastic group, porphyrin bands intensity was greater in approximate 30% cases. Classification employed by LDA and QDA tools had shown slightly better accuracy for QDA. The overall accuracy values obtained by PCA based QDA tool was 97%, 100%, 100% respectively. Results represent that fluorescence device along with the PCA-based QDA method could be an excellent replacement for in-vivo identification of oral cancer over the tissue biopsy.

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Declarations

Consent to participate Informed consent was attain from all participant (patients and volunteers).

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ZOOPLANKTON DIVERSITY WITH REFERENCE TO PHYSICO-CHEMICAL PARAMETERS IN LENTIC ECOSYSTEMS

Abstract

Zooplankton diversity is a key measure of the health and functionality of aquatic ecosystems, particularly lentic water bodies including ponds, lakes, and reservoirs. This work focuses on the zooplankton diversity in the lentic ecosystems, with an emphasis on its relationship with physico-chemical parameters. The study points out the role of zooplankton as bioindicators, reflecting changes in water quality and ecosystem dynamics. Chief physico-chemical factors such as temperature, pH, dissolved oxygen, turbidity, and nutrient levels are discussed in relation to their impact on the abundance, distribution, and community structure of zooplankton. The work synthesizes available data and studies to identify trends and patterns in zooplankton diversity across various lentic water bodies. It also addresses challenges in maintaining biodiversity and suggests strategies for sustainable management and conservation of freshwater ecosystems. Variations in their abundance were significantly influenced by seasonal changes and anthropogenic activities. Sites with high organic pollution exhibited a shift in community composition, favoring pollution-tolerant species. This work provides a foundation for further research on aquatic biodiversity and its ecological implications in lentic ecosystems.

Keywords: Zooplankton Diversity, Lentic Ecosystem, Physico-chemical parameters, Biodiversity.

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I. INTRODUCTION

Aquatic diversity of lentic water bodies consists of many organisms but out of which zooplankton play an important role. Zooplanktons are microscopic, free floating organisms which move at the compassion of the water movements and wind (Singh et al., 2021). Zooplanktons, as a important component of aquatic ecosystems, play an integral role in the functioning and health of lentic environments. These small, often microscopic organisms serve not only as indicators of water quality but also as essential links in the aquatic food web, facilitating energy transfer from primary producers, such as phytoplankton, to higher trophic levels, including fish and other aquatic fauna. Zooplankton, a diverse group of heterotrophic organisms, play an important role in aquatic ecosystems by consuming phytoplankton, regenerating nutrients through their metabolic processes, and ultimately transferring energy to higher trophic levels (Steinberg and Condon, 2009). Zooplanktons are heterotrophic planktonic organisms that occupy the middle trophic level in aquatic food webs, serving as a key connection between primary producers (phytoplankton) and higher trophic levels (fish) (Wetzel, 2001). Lentic ecosystems are dynamic environments characterized by a myriad of physical and chemical factors that influence the distribution and abundance of zooplankton species. Parameters such as temperature, pH, dissolved oxygen, conductivity, and nutrient levels (nitrogen and phosphorus) significantly affect the habitat and health of zooplankton communities. Understanding the interplay between these physicochemical parameters and zooplankton diversity is paramount for environmental management and conservation efforts, especially in regions undergoing anthropogenic pressures. In recent years, the significance of biodiversity in maintaining ecosystem resilience has gained prominence.

II. LENTIC ECOSYSTEMS: AN OVERVIEW

Lentic Ecosystems: Lakes, Ponds, Wetlands, and Phytotelmata lentic systems are aquatic bodies of water that have no pervasive downhill flow, and thus contrast with lotic streams and rivers (Thorp and Covich 2015). Lentic ecosystems are freshwater ecosystems characterized by still or stagnant water, such as ponds, lakes, swamps, and marshes. They contrast with lotic ecosystems, where water flows continuously, as in rivers and streams.

Characteristics

1. **Still Water:** The water in lentic ecosystems is relatively calm or stagnant.
2. **Stratification:** They often exhibit thermal and oxygen stratification, especially in larger water bodies like lakes.

3. **Nutrient Levels:** The nutrient content can vary, leading to classifications like oligotrophic (low nutrients), mesotrophic (moderate nutrients), or eutrophic (high nutrients).
4. **Biodiversity:** They host diverse flora and fauna, including algae, aquatic plants, invertebrates, fish, amphibians, and birds.
5. **Ecological Functions:** Habitat for aquatic organisms.
   - Water storage and groundwater recharge.
   - Support for nutrient cycling and sediment trapping.
6. **Dynamic Interactions:** Interactions among biotic (plants, animals, microorganisms) and abiotic (water, soil, nutrients) components shape these ecosystems.

Types of Lentic Ecosystems

1. **Ponds and Tanks:** Commonly found in villages for irrigation, livestock watering, and domestic use. Serve as key habitats for fish and amphibians.
2. **Lakes:** A lake is a large, inland body of standing water, formed by geological or climatic processes, and characterized by relatively slow water movement compared to rivers or streams (Wetzel, 2001).
3. **Marshes and Swamps:** Seasonal wetlands often form during the monsoon season, supporting migratory birds and aquatic vegetation.
4. **Man-made Water Bodies:** Created for agricultural purposes or as rainwater harvesting structures. Example: Check dams and small reservoirs.

Ecological Importance

1. Support local biodiversity, including native and migratory bird species.
2. Provide livelihood opportunities such as fishing and aquaculture.
3. Contribute to groundwater recharge in an agriculturally intensive district.
4. Act as carbon sinks, aiding in climate regulation.
5. Efforts to conserve and manage these ecosystems are crucial for maintaining ecological balance and supporting the livelihoods of local communities in the district.

III. ZOOPLANKTON DIVERSITY IN LENTIC ECOSYSTEMS

Zooplanktons are microscopic, free-floating organisms that play vital role in maintaining the structure and function of lentic ecosystems. They exhibit remarkable adaptability, thriving under diverse environmental conditions. Zooplanktons act as important ecological indicators, reflecting the presence or absence of specific fish species and their population densities. They also provide insights into the trophic status of water bodies and serve as bioindicators of organic and inorganic pollution. They form an essential link between primary producers (phytoplankton) and higher trophic levels, acting as a key component in aquatic food webs.

Zooplanktons are broadly classified into several groups, including Protozoa, Rotifera, Cladocera, Copepoda, Ostracoda, etc.

1. **Protozoa:** Protozoa are unicellular, eukaryotic microorganisms that live in water, soil, and as parasites in other organisms. They move using cilia, flagella, or pseudopodia and play essential roles in ecosystems, including nutrient cycling and disease transmission. Cryptosporidium and Giardia are protozoan pathogens that pose a significant global health burden, impacting both humans and livestock (McGrat et al., 2017).

2. **Rotifera:** Rotifers play vital role in many freshwater ecosystems (Segers et al., 2007). They are microscopic, multicellular aquatic animals belonging to the phylum Rotifera. Rotifera is a group of mainly freshwater invertebrates (Wallace et al., 2006). They are primarily found in freshwater environments and are known for their unique corona, a ciliated structure used for locomotion and feeding.

3. **Cladocera:** Cladocera, often known as water fleas, are small, planktonic crustaceans found in freshwater habitats. They belong to the class Branchiopoda and play a key role in aquatic ecosystems as primary consumers in the food chain. They are small-sized (0.2–6 mm, with one exception, Leptodora kindtii, reaching up to 18 mm) branchiopod crustaceans that primarily inhabit freshwater environments, including pelagic, littoral, and benthic zones (Fryer, 1987). Cladocera is chronological group of Palaeozoic origin (Dumont and Negrea, 2002), but their fossil remains are known only from the Mesozoic (Smirnov, 1971, 1992; Kotov & Korov-chinsky, 2006). Recently, Anderson et al. 2004 elucidated the crustaceans comparable to the Cladocera from the early Devonian.

4. **Copepoda:** Copepoda is a subclass of small crustaceans found in both marine and freshwater environments. They are among the most abundant zooplankton and play a major role in aquatic food webs as primary consumers and prey for larger organisms. They are small particularly freshwater crustaceans and ecologically successful taxa on Earth. They represent the leading and most varied groups of crustaceans (Hardy, 1970; Morales-Ramírez et al., 2014).

5. **Ostracoda:** Ostracoda, commonly known as seed shrimp, are small, bivalve-shelled crustaceans found in marine, freshwater, and terrestrial environments. They are characterized by their calcified carapace, which encloses their body like a clam shell. Ostracods are tiny, calcareous bivalved crustaceans that inhabit various aquatic environments and have existed throughout the entire Phanerozoic Eon (Puri, 1966; Yassini and Jones, 1995).

IV. ECOLOGICAL ROLES OF ZOOPLANKTON

Zooplankton play key ecological roles in aquatic ecosystems, acting as essential components of food webs and contributing to nutrient cycling, energy transfer, and ecosystem stability.

1. **Primary Consumers:** Zooplankton, such as copepods and cladocerans, feed on phytoplankton (microscopic algae), serving as primary consumers in aquatic food chains. By grazing on phytoplankton, they help regulate algal populations and maintain ecosystem balance.

2. **Trophic Link:** Zooplankton serves as an intermediate link, transferring energy from primary producers (phytoplankton) to higher trophic levels such as jellyfish, fish, and other predators. They are a key food source for larval and small fish, including commercially important species.

3. **Nutrient Cycling:** Zooplankton excrete organic and inorganic compounds that recycle nutrients in aquatic ecosystems. This process contributes to nutrient availability for phytoplankton growth, supporting primary production.

4. **Carbon Transport:** Through their feeding, digestion, and vertical migration, zooplankton play a major role in the biological pump, transporting carbon from the surface to deeper ocean layers. They consume organic material at the surface and release fecal pellets or die, contributing to carbon sequestration in the deep sea.

5. **Population Control:** By feeding on phytoplankton, zooplanktons prevent overgrowth of algal populations, which can lead to harmful algal blooms (HABs) and eutrophication.

6. **Biodiversity Support:** Zooplankton supports a diverse range of predators and maintains biodiversity within aquatic ecosystems.

7. **Indicator Species:** Certain zooplankton species are sensitive to environmental changes (e.g., temperature, salinity, and pollution) and can serve as bioindicators for assessing ecosystem health. In summary, zooplanktons are vital for maintaining the structure, function, and stability of aquatic ecosystems by mediating energy flow, nutrient dynamics, and biological diversity.

V. PHYSICO-CHEMICAL PARAMETERS AND THEIR IMPACT ON ZOOPLANKTON

Water is a vital resource for all living organisms on Earth. However, with the rapid growth of the human population, water resources are increasingly being polluted due to the discharge of domestic sewage, industrial effluents, urbanization, and agricultural activities. These activities introduce a wide range of chemical substances into water bodies, altering their natural composition. Bhandari and Nayal (2008) reported the physico-chemical and quality assessment of Kosi river water at Kosi sampling station during 2004-05. Shurin et al. (2010) suggest that anthropogenic increases in environmental variability due to climate change may profoundly affect biodiversity, particularly in freshwater ecosystems. Environmental and seasonal variations significantly influence species richness and diversity, with patterns varying across geographic regions). Life in aquatic environments is primarily governed by physico-chemical parameters, and any fluctuations in these parameters can significantly alter the ecosystem's balance. The physico-chemical parameters, including air temperature, water temperature, pH, electrical conductivity, alkalinity, total hardness, transparency, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), chlorides, sulfates, and phosphates, play a significant role in assessing water quality and determining the ecological health, composition, distribution and abundance of zooplankton in lentic ecosystems.

Key Physico-chemical Parameters Include

1. **Temperature:** Temperature significantly affects zooplankton metabolism, growth, and reproduction. Seasonal temperature variations can lead to shifts in zooplankton community composition. A rise in water temperature can enhance aquatic reactions (Drusilla et al., 2004). According to Shurin et al. (2010), greater temperature fluctuations across various time scales are

positively associated with zooplankton species richness, whereas chemical variability such as changes in pH or phosphorus tends to reduce diversity. Zooplanktons have specific temperature ranges in which they thrive. Extreme temperatures can reduce their metabolic rates or cause mortality. Warmer temperatures may accelerate growth, reproduction, and metabolic activity but may also lead to oxygen depletion, affecting zooplankton survival (Jonathan B Shurin et al., 2010).

2. **pH:** pH reflects the acidity or alkalinity of water, which affects enzyme activities and physiological processes in zooplankton. Low pH causes reduced zooplankton abundance, as well as decreased biodiversity and the loss of some species. Most zooplankton prefers a neutral pH (around 7). Variations in pH, especially lower acidic levels (due to pollution), can stress zooplankton, reducing their ability to reproduce and grow. Acidification (low pH) caused by pollutants or acid rain reduces zooplankton diversity and alters community structure.

3. **Dissolved Oxygen (DO):** The chemical and biological processes taking place in a water body depend on oxygen. DO is vital for the survival and respiration of aerobic organisms, including zooplankton (Wishner et al., 2018). Zooplankton requires adequate oxygen levels for respiration. Low DO concentrations often linked to eutrophication or pollution, can lead to hypoxia, negatively impacting zooplankton health leading to reduced activity, reproduction and their feeding behaviour. Oxygen depletion in stratified or eutrophic systems can result in mortality or forced migration.

4. **Salinity:** Salinity influences osmotic regulation and species composition in aquatic systems. Zooplankton species are adapted to specific salinity ranges (freshwater, brackish, or marine). Zooplankton species vary in their salinity tolerance. Changes in salinity, caused by freshwater influx or evaporation, can alter zooplankton community composition (Pali et al., 2022). Saltwater zooplankton may not survive in freshwater, and vice versa, affecting overall biodiversity. Salinity fluctuations, due to tides or freshwater inflows, can lead to shifts in community dynamics.

5. **Turbidity:** Turbidity affects light penetration and visibility, influencing zooplankton feeding efficiency. High turbidity, caused by suspended particles or pollutants, can interfere with zooplankton feeding (especially filter-feeding species) and visibility (Parveen et al., 2013). Increased turbidity reduces the availability of light for phytoplankton, indirectly

affecting zooplankton populations. Sediment particles can clog feeding structures or interfere with their movement. It may also affect their predator-prey interactions and hinder their ability to reproduce.

6. **Nutrient Levels (Nitrogen, Phosphorus):** Nutrients promote phytoplankton growth, which serves as the primary food source for zooplankton. Moderate nutrient levels enhance zooplankton productivity. Excessive nutrients (eutrophication) cause algal blooms, altering food quality and sometimes leading to oxygen depletion (Rahman et al., 2023). Algae provide food for zooplankton, but excessive blooms can result in oxygen depletion or the production of toxins, disrupting zooplankton populations.

7. **Pollutants (Heavy Metals, Pesticides):** Toxic substances like heavy metals (e.g., mercury, lead) or pesticides can accumulate in zooplankton, affecting their survival and reproduction. These pollutants may also interfere with their metabolic processes and cause long-term ecological damage. Toxic substances can reduce zooplankton survival, growth, and reproduction. Bioaccumulation of contaminants in zooplankton impacts higher trophic levels.

VI. METHODOLOGIES FOR ASSESSING ZOOPLANKTON DIVERSITY AND PHYSICO-CHEMICAL PARAMETERS

1. Zooplankton Diversity Assessment

Parameter	**Method/instrument**	**Description**
Sampling	Bango Nets	Used for collecting larger Zooplankton
	Multi-Net systems	Allows depth satisfied sampling
	Van Dorn Water sampler	Collect water samples at specific depth
Preservation	Ethanol (70%)	Alternative preservative for genetic studies
Identification	SEM (Scanning Electron Microscopy)	High resolution imaging of micro Zooplankton

	AI Based image recognition	Automated species classification using software
Quantitative Analysis	Laser optical Plankton Counter (LOPC)	Automated counting and size distribution analysis
	FlowCAM (Flow Imaging Microscope)	Combins flow cytometry and microscopy for analysis
Diversity Indices	Margalef's index	Measure species Richness
	Bray-curtis similarity	Use for community structure comparison

2. Physico-Chemical Parameter Assessment

Parameter	**Method/instrument**	**Description**
Temperature	Probe	Provide high efficiency temperature reading
pH	pH electrode Array	Multi point pH measurement in different depths
Dissolved Oxygen (DO)	Optical DO Sensor	Measure oxygen without reagents
Salinity	Refractometer	Simple methods for salinity estimation
Total Suspended Solids (TSS)	Filtration & Gravimetric Analysis	Measure suspended particles
Light Penetrations	PAR(Photosynthetically Active Radiation) Sensor	Determines light availability in water
Heavy Metals (Pb, Hg, Cd, etc.)	ICP-MS (Inductively coupled Plasma Mass Spectrometry)	Ultra-trace level detection of heavy metals

Organic Carbon	TOC Analyser (Total Organic Carbon)	Measure dissolved and particulate organic carbon
Alkalinity	Acid -Base Titration	Determines buffering capacity of Water
Microplastics	FTRI (Fourier Transform Infrared Spectroscopy)	Identify Plastic contamination in water samples

VII. CONSERVATION AND MANAGEMENT OF LENTIC ECOSYSTEMS

1. Conservation Approaches

- **Pollution Control:** Reduce industrial, agricultural, and domestic waste discharge.
- **Habitat Protection:** Preserve wetlands, riparian zones, and natural shorelines.
- **Biodiversity Conservation:** Protect native species and control invasive species.
- **Sustainable Water Use:** Implement policies for responsible water extraction and usage.
- **Climate Change Mitigation:** Promote afforestation, wetland restoration, and carbon sequestration initiatives.

2. Management Approaches

- **Ecosystem Monitoring:** Regular assessment of water quality and biodiversity.
- **Community Involvement:** Engage local communities in conservation efforts.
- **Legislation & Policies:** Enforce environmental laws and sustainable management practices.
- **Restoration Projects:** Implement habitat rehabilitation and pollution remediation programs. Effective conservation and management ensure the long-term health of lentic ecosystems, benefiting both nature and human societies.

VIII. CONCLUSION

The study on zooplankton diversity in lentic ecosystems points out the intricate relationship between water quality and biological diversity. The findings indicate that zooplankton composition and abundance are significantly influenced by parameters such as temperature, pH, dissolved oxygen, turbidity, nutrient levels (nitrates, phosphates), and organic matter content. Higher zooplankton diversity was observed in water bodies with moderate nutrient levels and stable ecological conditions, while degraded environments, characterized by pollution, eutrophication, and low oxygen levels, showed reduced diversity and dominance of pollution-tolerant species. The presence of certain indicator species also provided insights into water quality and ecosystem health. To maintain and enhance zooplankton diversity, effective conservation and management strategies should be implemented, including pollution control, habitat protection, and sustainable water resource management. Regular monitoring of physico-chemical parameters is essential to assess ecosystem health and prevent further degradation. This study underscores the importance of zooplankton as bioindicators and reinforces the need for integrated ecosystem management to ensure the sustainability of lentic water bodies.

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MELATONIN: A HORMONE OF DARKNESS AND AN ANTIOXIDANT MOLECULE IN IDIOPATHIC PULMONARY FIBROSIS – A REVIEW

Abstract

Idiopathic Pulmonary Fibrosis (IPF) is a chronic, progressive lung disease characterized by fibrosis and scarring of lung tissue, leading to a decline in respiratory function. While the exact cause remains unknown, oxidative stress and inflammation are key contributors to disease progression. Melatonin, often referred to as the "hormone of darkness," is a powerful antioxidant and immune regulator. Beyond its role in regulating the sleep-wake cycle, melatonin has gained significant attention for its protective effects in various diseases, including IPF. This chapter explores the biochemical properties of melatonin, its role in oxidative stress regulation, and its potential therapeutic applications in IPF.

Keywords: Melatonin, lung fibrosis, IPF, Circanual cycle, Biological clock, Inflammation, Pulmonary fibrosis.

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I. INTRODUCTION

Melatonin, often referred to as the "hormone of darkness," is a naturally occurring molecule that plays a crucial role in regulating circadian rhythms, sleep patterns, and numerous physiological functions. Secreted primarily by the pineal gland in response to darkness, melatonin influences a variety of biological processes, including immune modulation, mitochondrial function, and antioxidative defense. Over the years, research has expanded beyond its well-known sleep-regulating properties, revealing its potent antioxidant, anti-inflammatory, and antifibrotic effects. These attributes make melatonin a promising candidate for the treatment of chronic diseases characterized by oxidative stress and inflammation, including **idiopathic pulmonary fibrosis (IPF)**.

IPF is a progressive, debilitating lung disease of unknown cause that leads to excessive scarring (fibrosis) of lung tissue. It primarily affects older adults and is associated with a poor prognosis, as the fibrotic process impairs normal lung function, ultimately leading to respiratory failure. The median survival time after diagnosis is approximately 3-5 years, and current treatment options are limited, offering only a modest slowdown in disease progression rather than a cure. Despite extensive research, the precise mechanisms behind IPF remain incompletely understood. However, oxidative stress, mitochondrial dysfunction, and chronic inflammation are widely recognized as key drivers of disease progression.

One of the major challenges in IPF is the excessive production of **reactive oxygen species (ROS)**, which damages lung epithelial cells and promotes fibrotic changes. The lungs, being constantly exposed to environmental oxygen, are highly susceptible to oxidative damage. Under normal circumstances, endogenous antioxidants neutralize ROS, maintaining a balance between oxidative stress and cellular repair mechanisms. However, in IPF, this balance is disrupted, leading to persistent oxidative damage, chronic inflammation, and fibroblast activation. These processes drive the excessive deposition of extracellular matrix (ECM) components, resulting in irreversible lung scarring.
Given the central role of oxidative stress in IPF, **melatonin's strong antioxidant properties** offer a potential therapeutic advantage. Unlike conventional antioxidants that neutralize ROS in a single-step reaction, melatonin undergoes a cascade reaction, generating multiple antioxidant metabolites that further scavenge free radicals. Additionally, melatonin enhances the body's natural antioxidant defense systems by upregulating

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enzymes such as **superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx)**. This dual mechanism of direct ROS scavenging and indirect antioxidant enzyme activation makes melatonin a unique and powerful protective agent against oxidative stress.

Beyond its antioxidant effects, melatonin has been shown to **suppress inflammation and modulate immune responses**. It inhibits key inflammatory pathways, such as **nuclear factor-kappa B (NF-κB) signaling**, which plays a crucial role in cytokine production and fibrosis. Moreover, melatonin interferes with **transforming growth factor-beta (TGF-β) signaling**, a major driver of fibroblast differentiation into myofibroblasts, thereby reducing excessive collagen deposition in lung tissue.

As a naturally occurring molecule with minimal side effects, melatonin holds promise as a novel therapeutic option for IPF. While research is still in its early stages, preclinical studies suggest that melatonin may mitigate oxidative stress, reduce inflammation, and slow fibrotic progression in lung diseases. This chapter explores the potential of melatonin as a protective and therapeutic agent in IPF, delving into its biochemical properties, mechanisms of action, and emerging evidence supporting its role in combating lung fibrosis.

What is Idiopathic Pulmonary Fibrosis (IPF)?

Idiopathic Pulmonary Fibrosis (IPF) is a **chronic, progressive lung disease** characterized by **scarring (fibrosis) of lung tissue**, leading to **breathlessness and reduced lung function**. The term "idiopathic" means that the cause of the disease is unknown, though researchers believe a combination of **genetic, environmental, and cellular factors** contribute to its development.

In IPF, the lung tissue becomes **thickened, stiff, and scarred**, making it difficult for oxygen to pass into the bloodstream. This progressive fibrosis is caused by an **abnormal wound-healing response**, where lung epithelial cells become damaged and fail to regenerate properly. Instead of healing normally, **fibroblasts (scar-forming cells)** become overactive, depositing excessive amounts of **collagen and extracellular matrix**. This results in **permanent structural damage** to the lungs.

Some Major Symtomps of IPF

- **Breathlessness (Dyspnea):** The most common symptom, worsening over time.
- **Chronic Dry Cough:** Persistent, non-productive cough without an apparent cause.
- **Fatigue and Weakness:** Reduced oxygen levels impair energy production.
- **Clubbing of Fingers:** A sign of long-term oxygen deprivation.
- **Velcro-like Crackles:** Distinctive lung sounds heard through a stethoscope.

II. BIOCHEMISTRY OF MELATONIN

Melatonin (**N-acetyl-5-methoxytryptamine**) is a **small, lipophilic molecule** that is synthesized from the amino acid **tryptophan**. It is a **highly conserved molecule**, meaning it exists across multiple species, including plants, animals, and bacteria. While primarily secreted by the **pineal gland**, melatonin is also produced in peripheral tissues such as the **gastrointestinal tract, bone marrow, retina, skin, and lungs**, where it plays diverse physiological roles.

1. Melatonin Synthesis Pathway

The biosynthesis of melatonin occurs in a **four-step enzymatic process** starting from **tryptophan**:

Step 1: Tryptophan → 5-Hydroxytryptophan (5-HTP)

Enzyme: Tryptophan hydroxylase (TPH)

Reaction: Tryptophan is hydroxylated to form 5-hydroxytryptophan (5-HTP).

Step 2: 5-Hydroxytryptophan → Serotonin (5-HT)

Enzyme: Aromatic L-amino acid decarboxylase (AADC)

Reaction: 5-HTP undergoes decarboxylation to form serotonin (**5-hydroxytryptamine, 5-HT**).

Step 3: Serotonin → N-Acetylserotonin

Enzyme: Serotonin N-acetyltransferase (AANAT)

Reaction: Serotonin is acetylated to produce **N-acetylserotonin**.

Regulation: This is the **rate-limiting step** in melatonin synthesis and is **highly sensitive to light exposure**.

Step 4: N-Acetylserotonin → Melatonin

Enzyme: Hydroxyindole-O-methyltransferase (HIOMT, also called ASMT)

Reaction: N-acetylserotonin is methylated to form **melatonin**.

2. Regulation of Melatonin Production

a. **Light-Dark Cycle and Pineal Gland Secretion: Melatonin production follows a** circadian rhythm**, regulated by the** suprachiasmatic nucleus (SCN) **in the hypothalamus.**

   During darkness, SCN signals the pineal gland to **produce more melatonin**.
   During daylight, light exposure inhibits AANAT activity, leading to **reduced melatonin production**.

   The peak melatonin concentration occurs between **2–4 AM**, followed by a gradual decline in the morning.

b. **Extra-Pineal Synthesis:** Melatonin is also synthesized in other tissues (lungs, intestines, immune cells, mitochondria), where it functions locally as an antioxidant and anti-inflammatory molecule. Unlike pineal melatonin, which follows a circadian rhythm, extra-pineal melatonin synthesis is constant and independent of light exposure.

3. Melatonin Transport and Metabolism

a. **Transport in the Body**
   - Melatonin is **lipophilic** and easily crosses cell membranes, including the **blood-brain barrier**.
   - It circulates in the **bloodstream** either freely or bound to albumin.
   - Due to its small size, melatonin quickly **enters cells and mitochondria**, exerting **antioxidant and protective effects** at the cellular level.

b. **Metabolism and Excretion**
   - Melatonin is metabolized **primarily in the liver** by **cytochrome P450 enzymes (CYP1A2, CYP2C19)** into **6-hydroxymelatonin**.
   - It is then conjugated to **sulfates or glucuronides** and excreted through urine.

- The **half-life of melatonin** in circulation is **about 20-50 minutes**, making it a rapidly metabolized molecule.

4. Receptors and Mechanism of Action

Melatonin exerts its effects through two types of receptors**:**

a. G-Protein Coupled Receptors (GPCRs)

- **MT1 Receptor:** Regulates **circadian rhythms and sleep**.
- **MT2 Receptor:** Modulates **immune responses and vascular function**.

b. Nuclear Receptors

- Melatonin can bind to **ROR/RZR receptors**, influencing **gene expression** related to oxidative stress and inflammation.

c. Direct Antioxidant Action

- Unlike most hormones, melatonin **does not require receptors to function as an antioxidant**.
- It **scavenges free radicals** directly and stimulates **antioxidant enzymes**.

5. Functions Beyond Sleep Regulation

While melatonin is best known for **regulating sleep**, it also plays essential roles in:

- **Antioxidant Defense:** Neutralizes **reactive oxygen and nitrogen species (ROS & RNS)**.
- **Anti-Inflammatory Action:** Suppresses **pro-inflammatory cytokines** like TNF-α, IL-6, and IL-1β.
- **Mitochondrial Protection:** Prevents **mitochondrial dysfunction**, a key factor in **idiopathic pulmonary fibrosis (IPF)**.
- **Immune Modulation:** Enhances immune function and prevents excessive inflammation.
- **Fibrosis Inhibition:** Downregulates **TGF-β and fibroblast proliferation**, which contribute to **lung fibrosis in IPF**.

III. MELATONIN IN IPF: MECHANISMS OF ACTION

Idiopathic Pulmonary Fibrosis (IPF) is a **chronic, progressive lung disease** characterized by **excessive fibrosis, inflammation, and oxidative stress**, leading to **irreversible lung damage** and respiratory failure. Current treatments provide only **limited benefits**, making the search for **new therapeutic strategies** essential. **Melatonin**, widely recognized for its **antioxidant, anti-inflammatory, and antifibrotic properties**, has emerged as a promising candidate for IPF treatment.This section explores the **mechanisms by which melatonin exerts protective effects in IPF**, focusing on its ability to **reduce oxidative stress, inhibit inflammation, regulate fibrosis-related pathways, and enhance mitochondrial function**.

1. Melatonin as a Potent Antioxidant in IPF

Oxidative stress plays a central role in IPF, as **excessive reactive oxygen species (ROS) and reactive nitrogen species (RNS)** cause **lung epithelial cell damage, fibroblast activation, and collagen deposition**. The lungs are constantly exposed to environmental oxygen, making them particularly vulnerable to oxidative damage. In IPF, **antioxidant defenses are weakened**, allowing ROS to accumulate and contribute to fibrosis.

How Melatonin Counteracts Oxidative Stress

a. **Direct ROS Scavenging**
   - Melatonin is a **highly effective antioxidant** that directly neutralizes **hydroxyl radicals (•OH), superoxide anions ($O_2\bullet^-$), and peroxynitrite ($ONOO^-$)**.
   - Unlike typical antioxidants, melatonin **undergoes a cascade reaction**, generating multiple **antioxidant metabolites** that continue to neutralize ROS.

b. **Upregulation of Antioxidant Enzymes:** Melatonin **stimulates the production** of key antioxidant enzymes, including:
   - **Superoxide dismutase (SOD)** – Converts superoxide anions into less toxic molecules.
   - **Catalase (CAT)** – Breaks down hydrogen peroxide (H_2O_2) into water and oxygen.
   - **Glutathione peroxidase (GPx)** – Reduces lipid peroxidation, preventing membrane damage.

c. **Mitochondrial Protection**
   - **Mitochondrial dysfunction is a key factor in IPF progression**, as damaged mitochondria generate excess ROS.

- Melatonin accumulates in **mitochondria**, where it stabilizes the electron transport chain, preventing **mitochondrial ROS production and apoptosis of lung epithelial cells**.

2. Anti-Inflammatory Effects of Melatonin in IPF

Inflammation is a **major driver of fibrosis in IPF**, as activated immune cells release **pro-inflammatory cytokines** that promote fibroblast activation and lung tissue remodeling.

How Melatonin Reduces Inflammation

a. **Inhibition of NF-κB Pathway**
   - **Nuclear factor-kappa B (NF-κB)** is a key transcription factor that stimulates the production of **pro-inflammatory cytokines** like **TNF-α, IL-6, and IL-1β**.
   - Melatonin **blocks NF-κB activation**, thereby reducing inflammation and fibrosis.

b. **Suppression of Pro-Inflammatory Cytokines**
   - Melatonin lowers levels of **TNF-α, IL-6, and IL-8**, which are elevated in IPF patients.
   - It also reduces **macrophage and neutrophil infiltration**, decreasing lung tissue damage.

c. **Activation of Anti-Inflammatory Pathways**
   - Melatonin enhances the production of **IL-10**, an **anti-inflammatory cytokine** that protects lung tissue from excessive immune responses.

3. Antifibrotic Effects of Melatonin in IPF

Fibrosis in IPF is driven by **abnormal fibroblast activation**, excessive **collagen deposition**, and **dysregulated wound-healing responses**. The fibrotic process is largely controlled by **transforming growth factor-beta (TGF-β)**, a key cytokine that induces fibroblast differentiation into **myofibroblasts**—the primary cells responsible for **extracellular matrix (ECM) deposition**.

How Melatonin Inhibits Fibrosis

a. **Downregulation of TGF-β Signaling**
   - TGF-β stimulates fibroblast proliferation, ECM deposition, and myofibroblast activation.

- Melatonin **inhibits TGF-β expression and its downstream signaling pathways**, reducing **fibroblast activation and collagen production**.

b. **Suppression of Myofibroblast Differentiation:**
   - **Myofibroblasts** are highly contractile and contribute to lung tissue stiffness in IPF.
   - Melatonin **prevents fibroblasts from differentiating into myofibroblasts**, thereby slowing fibrotic progression.

c. **Reduction of Collagen Deposition and ECM Remodeling:**
   - In IPF, excessive **collagen (types I and III)** accumulates in lung tissue.
   - Melatonin decreases the expression of **collagen-producing genes (COL1A1, COL3A1)** and matrix metalloproteinases (MMPs), which regulate ECM degradation.

4. Mitochondrial Protection and Apoptosis Regulation

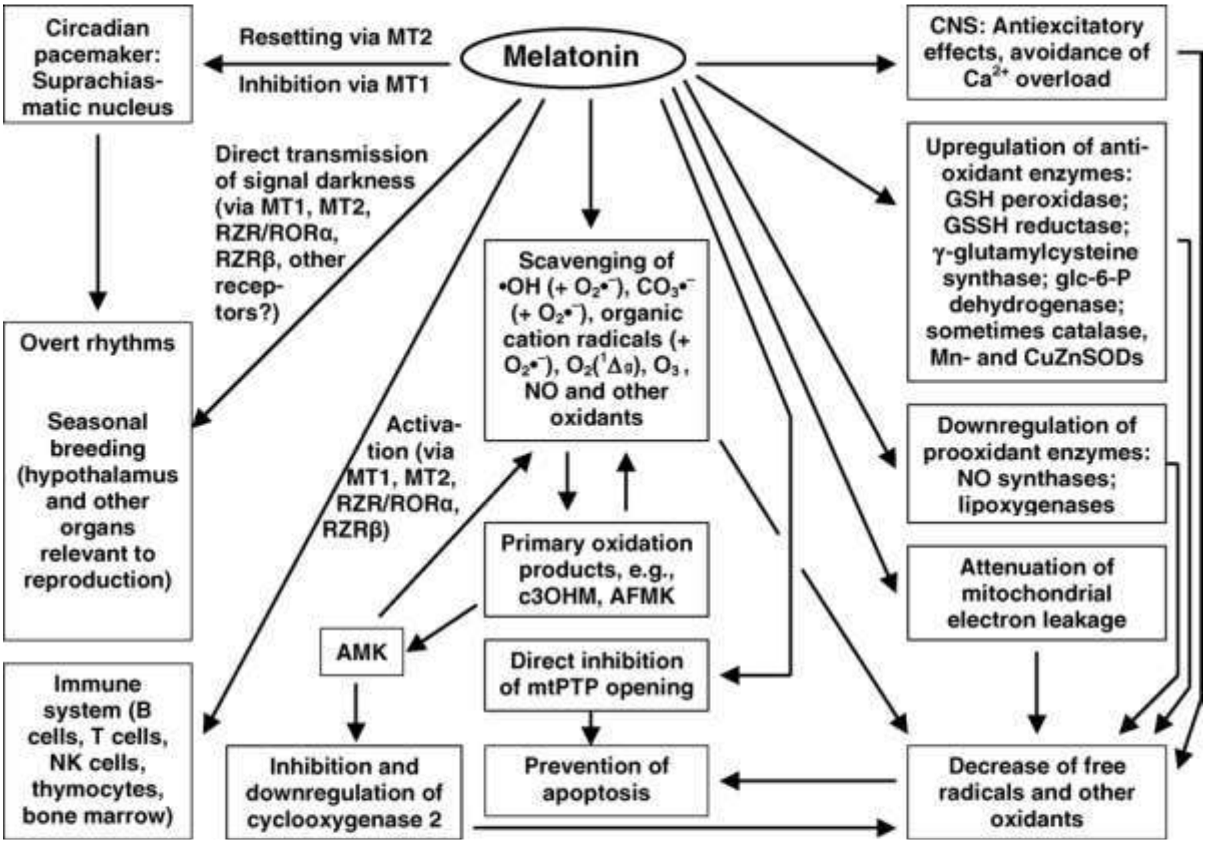
IPF is associated with **mitochondrial dysfunction**, leading to **increased apoptosis (programmed cell death) of alveolar epithelial cells**. When these cells die, the lung's repair mechanisms become **dysregulated**, triggering fibrosis.

How Melatonin Protects Mitochondria and Prevents Apoptosis

a. **Stabilization of Mitochondrial Membranes**
   - Melatonin maintains **mitochondrial integrity**, preventing **cytochrome c release** and **mitochondria-driven apoptosis** in lung epithelial cells.

b. **Inhibition of Pro-Apoptotic Proteins**
   - Melatonin **downregulates pro-apoptotic proteins** like **Bax** and **caspases (Caspase-3, Caspase-9)**, preventing excessive cell death.
   - It **upregulates anti-apoptotic proteins** like **Bcl-2**, which promote cell survival.

c. **Reduction of Endoplasmic Reticulum (ER) Stress**
   - **ER stress** is a major trigger for apoptosis in lung epithelial cells.
   - Melatonin mitigates ER stress by **reducing unfolded protein accumulation**, thereby preserving lung cell function.



(**Figure 1:** Overview of some major effects of melatonin on circadian and seasonal rhythms, immunomodulation, as an antiinflammatory, antioxidant, and antiapoptotic agent, including actions of its metabolites c3OHM, AFMK, and AMK. Reference. *R. Hardeland et al. / The International Journal of Biochemistry & Cell Biology 38 (2006) 313–316*)

IV. CLINICAL EVIDENCE FOR MELATONIN IN IPF

Idiopathic Pulmonary Fibrosis (IPF) is a progressive and life-threatening lung disease characterized by excessive fibrosis, inflammation, and oxidative stress. Given its potent **antioxidant, anti-inflammatory, and antifibrotic** properties, melatonin has been investigated as a potential therapeutic agent for IPF. Although most research on melatonin's role in IPF has been conducted in **preclinical models (cell cultures and animal studies)**, emerging clinical data suggest that melatonin may offer significant **protective benefits**.

This section explores **clinical evidence, case studies, and trials** evaluating the role of melatonin in IPF management.

1. Preclinical Studies Supporting Melatonin Use in IPF

Before discussing clinical trials, it is important to highlight **preclinical research** that has provided strong evidence for melatonin's **protective effects** in IPF models.

- **a. Animal Models of IPF (Bleomycin-Induced Fibrosis)**
  - In multiple studies, **melatonin treatment significantly reduced lung fibrosis, oxidative stress, and inflammation** in animal models of IPF.
  - A study in **bleomycin-induced pulmonary fibrosis mice** showed that **melatonin administration reduced TGF-β1 levels**, decreased **collagen deposition**, and improved **lung function**.
  - Melatonin also **restored mitochondrial function**, reducing **cellular apoptosis** in lung epithelial cells.

- **b. Cell Culture Studies**
  - **Fibroblast and alveolar epithelial cell cultures treated with melatonin** showed reduced **oxidative damage, lower TGF-β1 signaling, and decreased fibroblast proliferation**.
  - Melatonin was also found to **protect lung cells from apoptosis and mitochondrial dysfunction**, two major drivers of IPF progression.

These **preclinical findings** laid the foundation for **clinical trials** assessing melatonin's efficacy in human IPF patients.

2. Clinical Studies Evaluating Melatonin in IPF Patients

Pilot Studies and Case Reports: Although large-scale clinical trials are still lacking, smaller studies and case reports have shown promising results:

- **a. Melatonin Levels in IPF Patients**
  - A **study measuring melatonin levels in IPF patients** found that individuals with IPF had **significantly lower nighttime melatonin levels** compared to healthy individuals.
  - This suggests that **melatonin deficiency might contribute to disease progression**, highlighting the need for supplementation.

- **b. Melatonin Supplementation in IPF Patients**
  - In a **small observational study**, IPF patients who **received melatonin supplementation (3–10 mg/day) for 12 weeks** showed:
    - ➢ **Improved sleep quality** and reduced fatigue.

- **Lower oxidative stress markers** in blood tests.
- **Slight improvement in lung function parameters (FVC and DLCO)**, suggesting a potential protective role.

c. **Case Report on Melatonin as an Add-On Therapy**
- A **case report of a 67-year-old IPF patient** receiving **standard antifibrotic therapy (pirfenidone) along with melatonin (10 mg/day)** showed:
  - **Slower disease progression** compared to expected decline.
  - **Reduced inflammatory markers (CRP, IL-6 levels)**.
  - **Better overall quality of life and fewer respiratory symptoms**.

These **early findings** support the hypothesis that **melatonin could be beneficial as an adjunct therapy** in IPF treatment.

3. Potential Clinical Benefits of Melatonin in IPF

Based on current evidence, melatonin may offer the following **clinical advantages** for IPF patients:

a. **Improved Sleep Quality**
- Many IPF patients suffer from **sleep disturbances**, which worsen fatigue and disease progression.
- Melatonin **regulates circadian rhythms**, improving **sleep efficiency, reducing nighttime awakenings, and enhancing overall well-being**.

b. **Reduction in Oxidative Stress and Inflammation**
- IPF patients have **high levels of ROS and inflammatory cytokines**.
- Clinical studies have shown that **melatonin supplementation reduces oxidative stress markers**, which could **slow down fibrosis progression**.

c. **Potential Slowing of Disease Progression**
- While **no large-scale clinical trial has confirmed this yet**, some small studies suggest **melatonin may help preserve lung function** by reducing **collagen deposition and fibrosis-related signaling pathways**.

d. **Combination Therapy with Standard IPF Treatments**
- Melatonin may enhance the effects of standard IPF treatments like **pirfenidone and nintedanib**.

- It **complements antifibrotic drugs** by **targeting oxidative stress and mitochondrial dysfunction**, two key factors in IPF pathology.

4. Current Challenges and Future Directions

Challenges in Clinical Research

a. **Lack of Large-Scale Clinical Trials**
   - Most evidence on melatonin's effects in IPF comes from **animal studies and small observational trials**.
   - **Randomized controlled trials (RCTs)** are needed to confirm its **therapeutic potential, optimal dosage, and long-term safety**.

b. **Dosage and Timing Uncertainty**
   - Clinical studies have used varying doses (3 mg to 10 mg daily), making it **unclear what the most effective dose for IPF would be**.
   - **Nighttime dosing** may be more beneficial due to melatonin's natural circadian rhythm.

c. **Interaction with Existing IPF Medications**
   - More studies are needed to determine how melatonin interacts with **pirfenidone, nintedanib, and other IPF treatments**.

5. Future Research Directions

To establish melatonin as a **viable treatment for IPF**, the following research areas need to be explored:

a. **Large-Scale Randomized Clinical Trials (RCTs)**
   - Well-designed **RCTs involving IPF patients** are required to confirm melatonin's **efficacy, safety, and long-term benefits**.

b. **Personalized Medicine Approaches**
   - Some patients may benefit more than others from melatonin therapy.
   - Future research should explore **genetic and biomarker-based approaches** to identify **which patients respond best to melatonin supplementation**.

c. **Combination Therapy Studies**
   - Trials should investigate **melatonin as an add-on therapy** with **standard IPF medications** to see if it enhances their effects or reduces side effects.

d. Extended Studies on Melatonin's Mitochondrial Protection

- Since **mitochondrial dysfunction is a key factor in IPF progression**, future research should focus on **how melatonin improves mitochondrial function in human lung tissue**.

V. CONCLUSION: THE ROLE OF MELATONIN IN IPF MANAGEMENT

Idiopathic Pulmonary Fibrosis (IPF) remains a devastating lung disease with limited treatment options, primarily focusing on slowing disease progression rather than reversing fibrosis. The search for **novel therapeutic strategies** has led researchers to investigate **melatonin**, a naturally occurring hormone with potent **antioxidant, anti-inflammatory, antifibrotic, and mitochondrial-protective** properties. **Melatonin as a Powerful Antioxidant** IPF is driven by **excessive oxidative stress**, leading to **alveolar epithelial cell damage, fibroblast activation, and lung tissue remodeling**. Melatonin **scavenges free radicals** and **upregulates endogenous antioxidant defenses**, helping protect lung tissue from further damage. **Anti-Inflammatory and Antifibrotic Actions**. Melatonin, often referred to as the **"hormone of darkness,"** is emerging asa **beacon of hope** for IPF patients. While more clinical trials are needed, existing evidence highlights its **potential to mitigate oxidative stress, inflammation, and fibrosis**, making it a **compelling candidate for future IPF therapies**. If successfully integrated into treatment regimens, melatonin could improve **patient quality of life and disease prognosis**, offering **a new horizon in IPF management**.

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INTEGRATED MANAGEMENT OF *ALTERNARIA BRASSICAE* CAUSING ALTERNARIA BLIGHT OF INDIAN-MUSTARD (*BRASSICA JUNCEA*)

Abstract

India is one of the largest Indian-mustard (Brassica juncea) growing countries in the world occupying the third position in area and in production after China and Canada. Indian-mustard is the second most important oilseed crop in the country after groundnut. Rajasthan is the largest Indian-mustard producing states in India whereas Madhya Pradesh, Haryana, Uttar Pradesh, West Bengal, Jharkhand, Assam, Bihar and other states hold the top position in production. In India, Alternaria blight was first time reported of the fungus from Pusa, Bihar (1928) on Sarson (Herbarium material). The pathogen was readily isolated on two per cent PDA medium by usual method and its pathogenicity was proved following the Koch's postulates. Alternaria brassicae is moderately fast growing colony, as ashy grey, fluffy, circular and later turning into dark greenish olive. Septate mycelium branched, thin, hyaline and smooth. Conidiophores are simple, septate, amphigenous, unbrached, geniculate, olive brown in color. Conidia obclavate, muriform, elongate, oval and cylindrical to long beak and transverse to longitudinal septa with pale brown in color. Disease cycle of Alternaria blight survives of pathogen through seed, plant debris, soil and also on weed hosts. Symptoms on leafs circular, zonate, light brown to dark brown in color with

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distinct concentric rings. On stem linear to sunken, whereas on pods form of circular, dark brown to black lesions. Alternaria blight has been reported in all states of India, but in Eastern UP seen with varying severity and yield losses. Cultural practices are known from ancient (oldest) times for reduction in disease intensity. DI was reduced when shifting in date of sowing was made for many of the diseases in different crops. For management of Alternaria blight by fungicides like Mancozeb, Iprodione, Topsin-M, Achook, Ridomil-MZ, Ziram, Captan and Blitox-50 inhibit the fungus completely. Zineb, Thiram, Duter, Calixin, Bavistin and Kavach effective than the remaining fungicides but Karathane was least effective fungicides. Tested of plant extracts like Madar, Datura and Neem were superior but Sadabahar was least effective plant extract. Spraying of Mancozeb and Iprodione was most effective in minimizing the DI but remaining fungicides and plant extracts are all less effective in order of superiority.

Keywords: Brassica, pathogenicity, alternaria blight, fungicides

I. INTRODUCTION

Indian-mustard (*Brassica juncea* (L.) Czern & Coss) also known as the name of rapeseed-mustard, Raya, Rai, and Laha. It is the most important edible oilseed crop in India and abroad which is consumed by human being in the form of oil, vegetables and condiments. It's belongs to the family of plant *Brassicaceae* or *Cruciferae*.

Indian-mustard is an important oilseed crop which occupies almost 80 per cent of the 262.06 lakh hectares cropped under oilseed *Brassica* crops in India **(Anonymous, 2017-18).** The total area, production with productivity during 2016-17 oilseeds to the India were 262.06 lakh hectares, 32.10 million tonnes, and 1225 kg/ha, respectively **(Anonymous, 2017-18).** Alternaria blight is the most common or widespread and destructive disease in Indian-mustard and is caused by *Alternaria brassicae* (Berk.) *Sacc.* It's infecting the all above ground parts of plant. It has been reported from different continents of the world. Mostly in India, the disease is very severely mainly in the states of Himachal Pradesh, Haryana, Rajasthan, Uttar Pradesh, UttaraKhand, Bihar and MP, but appears in almost all the above parts of the country. The symptoms of the disease forming brown to black spots with concentric rings on leaf's, stem and pods **(Meena *et al*. 2010). Chadar *et al.* (2016)** recorded 23.9-62.0 percentage disease intensity of leaf blight of Indian-mustard which occurred in widely placed region of Bundelkhand, India.

II. HISTORY AND DISTRIBUTION

Alternaria blight of Oilseed Brassicas is known to be incited by three types of species namely *Alternaria brassicae* (Berk.) Sacc., *Alternaria brassicicola* (Schw.) Wiltshire., and *Alternaria raphani* Groves and Skolko **(Jasalavich *et al.* (1995), Saharan and Mehta, (2002).** The genus of *Alternaria* includes parasitic, saprophytic and pathogenic species. *Alternaria brassicae* was first time reported from England by **(Berkeley, 1836)** under the name of *Macrosporium brassicae* Berk. In India, the disease of Alternaria blight was first reported of the fungus was made by **(Mason, 1928)** from (Pusa, Bihar) on *Sarson* (Herbarium material). Since then it has been reported from different parts of the country. This disease was first reported by **(Dey, 1948)** at Kanpur in Uttar Pradesh in India, it was probably first noticed on *Sarson* (*Brassica campestris* var. *sarson*) in 1901 at Tirhoot (Trihut) nearby Pusa, Bihar **(Butler, 1918 and Bhownik, 2003).** Alternaria blight of Indian-mustard is the one of the most widespread and destructive disease in India, particularly in the Indo-

Gangetic plains **(Vasudeva, 1958).** The disease is also called the other names dark spot, **Louvet, (1958)** or grey spot, **McDonald, (1959)** based on characteristics symptoms produced on the host.

1. Pathogen

The genus of Alternaria was described by **(Nees in 1816)** with *Alternaria tenuis* as the type and only member of the genus, which later was renamed as *Alternaria alternata* as type species. No clear consensus on Alternaria taxonomy emerged for over 100 years. **(Elliot, 1917)** suggested that the genus could be organized into six groups based upon common characteristics of conidial length, width and septation with each group designated by a typical species. (**Neergaard, 1945)** proposed three sections for the genus based upon the formation of conidia in long chains (Longicatenatae), short chains (Brevicatenatae), or singly (Noncatenatae). The genus *Alternaria* belongs to the Phylum Ascomycota which consists of both saprophytic and pathogenic species. Alternaria belongs to the class Dothideomycetes, order Pleosporales and family Pleosporaceae. *Alternaria* species is characterized by formation of polymorphous conidia either singly or in short or chains with longitudinal and transverse septa with long or short beaks.

Chattopadhyay, (2008) observed Alternaria blight disease caused by *Alternaria brassicae* (Berk.) Sacc. and *Alternaria brassicicola* (Schw.) Wiltshire, is one among the important diseases of Indian-mustard, which has been reported from all the continents of the world, causing 10-70% yield losses depending on the crop species, being high in *B. rapa* with 35-40% in Indian-mustard.

2. Isolation and Purification

Chahal and Lanans (1980) revealed that seed infection by *Alternaria brassicae* was confined to discolored grey seeds and could not be eliminated by surface sterilization with 2% Sodium hypo-chloride for one or ten minutes. Conidia of *Alternaria brassicae* were present at all times over fields of *sarson* during the growing season. **Galveze *et al.* (1988)** found black, round or elongated necrotic spots on rape (*B. juncea*).

Verma and Saharan (1993) observed the morphological characters; the pathogen isolated was identified as *Alternaria brassicicola. Alternaria brassicae* and *Alternaria brassicicola* were isolated from rape and Indian-mustard. *Alternaria raphani* was most common on radish but also occurred on other *Brassica* vegetable and oil yielding crops **Petric, (1974)** reported that *Alternaria carthami* occurred on 95% of untreated safflower seeds.

Singh *et al.* (2009) observed the five disease samples were collected from 18 districts of Haryana (India) at 20 to 25 km intervals. The spot/lesion size on leaves of the collected samples ranged from 3.0 to 11.5 mm. These samples were isolated and purified by single spore technique to study the morphological, cultural and radial growth behavior at 20 and 25°C.

3. Morphological Characters of the Pathogen

Singh and Gupta (1953) observed that the conidia of *Alternaria brassicae* were usually greenish brown in colour, somewhat bottle shaped, having a long colorless beak at the tip and two to five cross septa and one or two longitudinal septa at proper end.

Changsri (1961) the lesions produced by *Alternaria brassicae* on crucifer crops were grey, dense and sparsely covered with brown conidiophores and conidia. The conidia on the host were 86.4-252 x 14.7-32.6 µm (mostly 10-11 transverse septa with long beak and a usually forming singly). The fungus was sporulated poorly on many agar culture media.

Singh *et al.* (2009) the radial growth varied from 34.6-81.1 mm with creamish, light brown to dark brown in colour and compressed to fluffy mycelial growth. The average conidial length ranged from 117.0 to 192.0 µm and breadth from 14.0 to 24.0 µm. The conidial beak length varied from 42.0 to 116.0 µm, number of horizontal and longitudinal septa ranged from 6 to 9 and vertical and transverse septa ranged from 1 to 3 and average distance between two septa have also been determined.

Khulbe *et al.* (2011) observed of morphological of twenty isolates of *Alternaria brassicae* collected from different locations of *Tarai* region of Uttarakhand, infecting rapeseed and mustard were studied. Among the tested isolate there was a distinct difference in terms of mycelial growth, colony characters, conidial length and conidial beak length. The isolates showed varied growth from slow to fast with varying margin type and colony colour, sectoring was observed in almost all except ABD, ABN and ABR. The average conidial body length range varied from 21.00 µm to 298.00 µm. The average minimum conidial length was observed in isolate ABC (55.23 µm) and maximum in ABD

(152.17 µm). The beak length of the conidia range varied from 12.00 µm to 144.00 µm however average was minimum in ABH (35.50 µm) and maximum in ABL (88.40 µm).

Goyal *et al.* (2011) noticed the cultural characteristics among 13 representative Indian geographical isolates from 219 collections of *Alternaria brassicae*, the causal agent of Alternaria blight of rapeseed-mustard, was studied. All the isolates showed high level of variability *In-Vitro* in respect of conidia length, width, beak length and number of septa. Substantial variation was found in mycelial growth, sporulation among these isolates in different nutrient media. All the isolates did not grow and sporulate abundantly on the same nutrient medium. However, on an average Asthana and Hawker's medium was good for growth on culture medium.

Recorded the morphological character of *Alternaria brassicicola* found the best growth 62.8 mm and sporulation 21.30x106spores/ml on Potato Dextrose Agar (PDA) medium followed by Richard's and Czapeck's medium, **(Kumawat *et al.* 2011).**

Singh *et al.* (2012) studies the morphological character of all the 25 isolates of *Alternaria brassicae* were grouped into three broad groups' *viz.*, ab1, ab2 and ab3. Isolates of group ab1 are whitish brown, appressed fast growing colonies with high sporulation. Isolates of group ab2 are white or whitish with brown margin, slightly fluffy medium growth with sparse to low sporulation. Isolates of group ab3 were grayish white, fluffy slow growing with moderate sporulation. Pathological behavior of representative isolates of *Alternaria brassicae* from each group differed on twelve host cultivars of rapeseed and mustard. ab5 isolates appeared to be most virulent and ab4 isolate show least virulence.

Shakti *et al.* (2013) observed the variation in radial growth, sporulation and conidial septation. The maximum radial growth (52.5mm) and good sporulation were observed in isolates from Sarsaul and the minimum growth and fair sporulation was observed in isolates of Billhaur Kanpur district showing dark brown colony characteristics. As far as conidial septation is concerned, the horizontal septation varied from 4-13 and vertical from 0-6. The septum distance between two septa and length of beak also showed some variation.

Selvamani *et al.* (2013) observed the forty isolates of *Alternaria brassicae* were collected from different cauliflower, cabbage and mustard growing locations of

India and characterized for cultural, morphological, pathogenic variations. All the isolates showed high level of variability *In-vitro* in respect to mycelial growth, growth pattern and sporulation. The Jaipur isolate (AB-16) showed higher growth (86 mm) in PDA and Coimbatore isolate (AB-37) showed least growth (35 mm) in PDA. All the isolate depicted high growth rate and high number of spore production on Cauliflower leaf extract Agar (CLEA) followed by PDA and Czapek's Dox Agar (CDA). Substantial variation was found in spore morphology in respect to conidial length, width and number of septa. Average conidial length and width were varied from 34.2-99.2µm and 6.1-14.18µm, respectively. Horizontal septa showed higher degree of variation than vertical septa. Number of horizontal and vertical septa ranged between 4.0-8.2 and 0.2-1.8, respectively.

Singh *et al.* (2014) recorded in laboratory condition in respect of radial growth, conidia length, width, beak length and number of septa. To studied these morphological and radial growth behaviour on PDA at 25±1°C. Radial growth varied from 70.70 to 90.00 mm. The average conidial length ranged from 105.75 to 136.73 µm and width from 11.13 to 15.70 µm. The conidial beak length varied from 50.00 to 71.08 µm. Number of transverse and longitudinal septa ranged from 6.00 to 8.00 and 0.25 to 2.75 respectively.

Pramila et al. (2014) *noticed the Alternaria* blight (*Alternaria brassicae*) causes severe foliar damage to Indian mustard in Uttarakhand. Ten (10) isolates of *A. brassicae* were collected from different hosts and characterized for cultural, morphological, pathogenic and molecular variations. *A. brassicae* colonies varied in their cultural behaviour ranging from cottony, flurry to feathery, with smooth to rough margins. Colour of colonies ranged between white, off white to light brown. Colony growth varied from slow, medium to fast with fast growth in isolate KM and least in JD on the potato dextrose agar (PDA) medium. Significant morphological variations in conidia length, conidia width, and number of horizontal septa were observed in the isolates. Average conidial size ranged from 105 to 135 × 10 to 20 µm.

Singh *et al.* (2014) recorded the Radial growth varied from 70.70 to 90.00 mm. The average conidial length ranged from 105.75 to 136.73 µm and width from 11.13 to 15.70 µm. The conidial beak length varied from 50.00 to 71.08 µm. Number of transverse and longitudinal septa ranged from 6.00 to 8.00 and 0.25 to 2.75 respectively.

In the respect of radial growth, conidial length, width and number of septa was noticed in *In-vitro* condition. Radial growth varied from 76.60 to 90.00 mm and 62.37-88.57 mm at 25^{0}C and 100% RH respectively. The average conidial length ranged from 104.48 to 139.25 µm and width from 10.58 to 14.83 µm. Number of transverse and longitudinal septa ranged from 6.25 to 9.75 and 1.00 to 2.50 respectively. Colony colour, appearance, margin and zonation were also noted on PDA medium, **Singh and Singh, (2014).**

Mehra *et al.* (2017) observed the *Alternaria brassicae* in isolates irrespective to geographical locations and *Brassica* spp. Maximum radial growth (82.0 mm) was in AB-*Brassica juncea* Pantnagar isolate, while minimum in AB- *Brassica caulorapa* (49.7 mm) on PDAin colony colour, appearance, margin and zonation number. Substantial variations were found in spore morphology in respect to conidial length, width and number of septa. Average conidial length and width were varied from 29.0-6.6 x 185.3-28.2µm. Maximum spore length and width was in AB-*Brassica carinata* isolate (185.3 x 25.6 µm), while minimum in AB-*Brassica caulorapa* (29.0 x 6.6µm). Number of horizontal and vertical septa ranged between 3.50-14.75 and 0.75-5.0 respectively.

Studies *In-vitro* in respect of radial mycelial growth, colony colour, sub-surface colour, colony shape, colony texture, zonation (surface and sub-surface), length and width of conidia, beak length and number of septa. The maximum and minimum radial mycelial growth was recorded 90 mm in and 83.67 mm in respectively at 14 days after incubation. Significant variation in conidial length, width, beak and no. of conidia observed in all isolates. The length of conidia ranged from 41.56 to 117.54µm with 3 to 11 transverse and 0 to 3 vertical septa. The width and beak length varied from 10.34 to 23.12 µm and 16.78 to 72.65 µm respectively. Surface colour was olivacious green to black and circular shaped colonies were observed in all isolates on PDA medium. Colony texture was cottony to velvety, subsurface colourvaried from light brown to black and pinkish. Zonation found in some isolates and some did not produce on both surface and subsurface. All conidia were murifrom and light brown to deep brown in colour, **(Monowara *et al.* 2017).**

4. Disease Cycle

The Alternaria survives through seed, plant debris, soil and also on weed hosts. It has been proved that Alternaria does not survive through seed to cause infection in the coming season due to high temperature conditions during summer months in storage houses of North India **(Chahal, 1981).** However, the possibility of its survival through seed on hills cannot be ruled out. *Alternaria brassicae* survives with plant debris buried in the field at 7.5 cm depth in the form of microsclerotia and chlamydospores formed in the infected leaves. *Alternaria brassicae* is known to become seed-borne although this mode of survival and dispersal is not very significant. The main mode of perpetuation is on debris of infected plants. **Mehta *et al.* (2002 a)** has reported that diseased debris placed in deep freezer conditions (-10°C) were able to cause 100 per cent infection in the coming season when mixed in the soil as compared to the debris placed in the field and laboratory conditions. It was further confirmed that pathogen survive in field for two years in the diseased debris collected from the temperate conditions (Canada) as compared to the Sub-Tropical conditions of India **(Mehta and Tewari, 2002)**. Local dispersal is through air, splashes and occasional driving rain drops. The disease cycle of the pathogen is presented in the **Fig.1.**

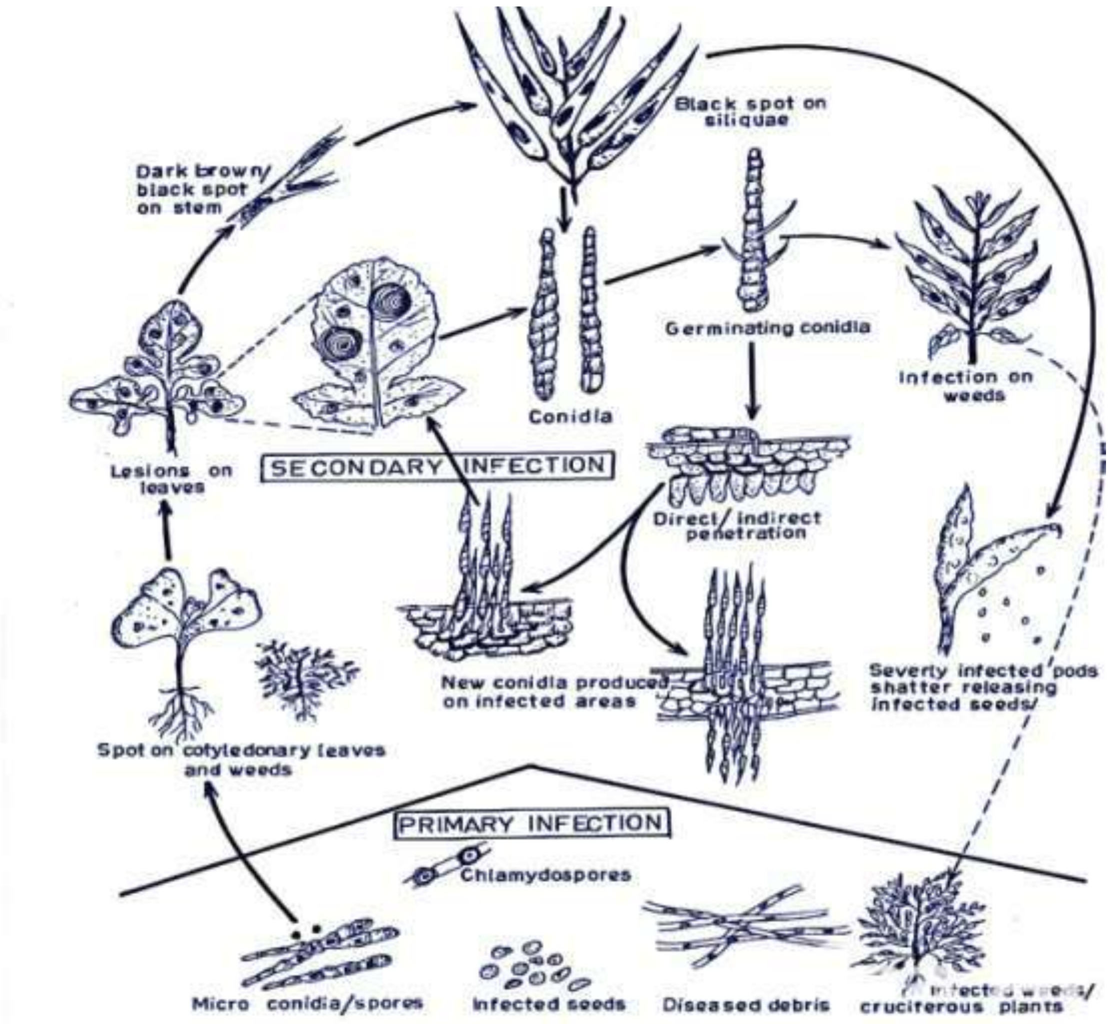

Figure 1: Disease cycle of Alternaria blight of Indian-mustard

5. Symptomatology and Yield Losses

Chupp and Sherf (1960) noticed the Alternaria symptoms when the older plants become infected often occur on the older leaves, since they are closer to the soil and are more readily infected as a consequence of rain splash or windblown rain. Late infection, or infection of older leaves, does not characteristically reduce yields and can be controlled through intensive removal of infected leaves.

Ansari *et al.* (1988) noticed the loss in oil content of the seed from diseased plants of rapeseed cultivars over the seeds from healthy plants ranged between 14.6 and 36.0 per cent.

Verma and Saharan (1994) observed the four Alternaria species cause symptoms in the seedling stage on cotyledons and in the adult stage on leaves, leaf petiole, stem, inflorescence, siliquae and seeds. In general, symptoms are similar on all the infected host species in the form of lesions. There may be variations in shape, size, colour, formation of concentric rings, yellow halo around the lesions under different ago-ecological zones, host genotypes, nutritional status of soil, and pathotypes involved.

Shrestha *et al. (*2005) noticed the Alternaria leaf blight disease caused by *Alternaria brassicae* in mustard (*Brassica juncea* (L.) Czern and Coss) the average yield loss was estimated to be in the range of 32 to 57%. The disease showed a negative effect on oil content causing losses on oil between 4.2 to 4.5%.

Meena *et al.* (2010) observed the symptom variability exhibited on leaves of different host differentials of *Brassica juncea* due to *Alternaria brassicae* isolates is in the form of medium size, circular, grayish brown spots, 6 to 8 mm in diameter, with three regular concentric raised rings of dark brown in colour.

Kumar *et al.* (2014) studies the alternaria leaf blight also known as Alternaria dark spot is the most destructive disease of oilseed brassicas species in all the continents. This disease is known to be incited by *Alternaria brassicae, Alternaria brassicicola* and *Alternaria raphani* singly or by mixed infection. Alternaria leaf spot pathogens are necrotrophs and produces lesions surrounded by chlorotic area on leaves, stems and siliquae causing reduction in the photosynthetic areas, defoliation and early induction of senescence.

Das (2015) studies of Alternaria blight of rapeseed-mustard caused by the fungus *Alternaria brassicae* (Berk.) Sacc. is an economically important disease and occurs regularly during the winter season in West Bengal with an average loss in yield of about 47%.

Singh and Singh (2016) observed the diseases appears as black spot but later on enlarge and develops into prominent round spots with concentric rings. After sometime these spots were large patches showing blight and cause defoliation in severe cases. The spots on the mid-ribs of the leaves are linear and sunken. Circular to linear lesions also develop on stem and pods, which elongate at later stages. Infected pods produce small, discoloured and shrivelled seeds.

Indian mustard (*Brassica juncea*) is an important oilseed crop in India. Among various diseases infecting mustard crop, Alternaria leaf spot also known as Alternaria blight is incited by fungus *Alternaria brassicae*, which majorly affects the crop production leading to a yield loss of up to 70 %, **(Gupta *et al.* 2020).**

Kumar and Shete (2021) observed the Alternaria leaf spot pathogen produces lesion around the leaves, stem, and the siliquae which cause reduction in defoliation. These pathogens are seed borne, soil borne, and airborne diseases. Alternaria leaf spot diseases caused by the heavy rainfall and the weather with the highest diseases incidence

III. MANAGEMENT OF DISEASE

1. Cultural Practices

Dasgupta, (1991) studies in West Bengal, delay in sowing of Indian-mustard by one month, beyond 22nd October, increased the incidence of *Alternaria brassicae* and *Alternaria brassicicola* on leaves by 37 % and pods by 31%.

Srivastava *et al.* (2005) reported relatively higher Alternaria blight severity in early sown crop (September last week to October first week) than normal (15 to 30 Oct.) and late (Nov. 15 to Dec. 10) sown crop.

Khatun *et al.* (2011) a study was carried out to find out the effect of sowing dates and varieties on the severity of *Alternaria* blight of mustard. Seeds of eight mustard varieties were sown on four different dates. Data on severity of the disease and seed yield were recorded. Disease severity differed significantly among the varieties. *B.campestris* varieties showed the higher disease severity compared to *B. napus* and *B. juncea*. The lowest disease severity was recorded in BARI Sarisha 11 which produced the highest seed yield. Percentages of leaf area diseased, leaf infection, siliqua infection, and spots per siliqua were found lowest under 21 October sowing, which were statistically lower than other sowing dates. The highest seed yield (1727 kg/ha) was recorded under 01 November sowing followed by 21 October sowing. Combination of sowing dates and varieties had a significant influence on disease severity and seed yield. Early sown (21 October and 1 November) BARI Sarisha 11 showed less disease severity and gave higher seed yield than other treatment combinations.

Kumar and Singh (2012) observed the Alternaria blight of yellow *sarson* caused by *Alternaria brassicae* (Berk) Sacc. and *Alternaria brassicicola* (Schwein) Wiltshire through management by cultural practices *viz.,* two dates of sowing and two varieties. First date of sowing *i.e.*20 October showed lower Alternaria leaf blight intensity of 41.59%, pod blight of 24.58% and higher seed yield of 1371.05 kg ha^{-1} as compared to 30th October sown crop.

2. Plant Extracts

Chand and Singh (2004) studies on different plant extract against the Alternaria blight of mustard. The spray with bulb extract of *Allium sativum* showed the lowest disease intensity (2.87%), followed by *Eucalyptus globulens* (5.3%) and *Azadirachta indica* (7.4%) compared to 20% in the control. *Jatropha multifida* and *Calotropis procera* were comparatively less effective than the other plant extracts, but these also reduced the disease intensity from 20% to 7.5 and 11.9%, respectively.

Patni *et al.* (2005) evaluated six plant extracts *Azadirachta indica*, *Parthenium hysterophorus, Calotropis procera*, *Datura alba (Datura metel)*, *Eucalyptus globulus,* and *Piper longifolia* against Alternaria blight (*Alternaria brassicae*) of Indian mustard and reported Eucalyptus (*Eucalyptus globulus*), Ashok (*P. longifolia*), and Calotropis (*Calotropis procera*) extracts in that order, were promising in limiting the growth and sporulation of the pathogen, *P. hysterophorus* extract promoted growth of the fungus.

Patni and Kolte (2006). recorded the extracts tested, Eucalyptus leaf extracts showed significant in radial growth, sporulation and spore germination. *In-vitro* condition leaf extracts of *Eucalyptus, Ocimum* and *Anagallis* showed maximum reduction (92.5%, 91.6%, 91.4% decrease over check respectively) in radial growth whereas *Ocimum*, *Eucalyptus* and *Urtica* showed minimum sporulation intensity (0.26, 0.28, 0.81x10^5 respectively). Significantly lowest reduction of spore germination was observed with *Urtica* followed with *Ocimum* and *Eucalyptus* (86.6%, 79.4% and 78.9% respectively),

Meena and Sharma (2012) studied the antifungal properties *L. inermis, E. chiapasana, C. congesta, C. carandas, F. benghalensis, Vinca rosea (C. roseus), N. oleander, Z. officinale, S. jambolanam, (Z. cumini), R. communis,* and *Aloe barbadensis (Aloe vera)* and bulb *A. sativum* extracts at 2 and 5% concentration against *Alternaria brassicae In-vitro*. They also reported maximum inhibition of mycelial growth with the extract of *A. sativum* at both concentrations, followed by the extracts of *L. inermis* (30.00%), *E. chiapasana* (25.5%), *R. communis* (16.8%) and *Z. officinale* (16.3%) at 5% each.

Ganiel *et al.* (2013) observed five plants extracts *viz., Azadirachta indica, Lantana camara, Ocimum sanctum, Eucalyptus globulus* and *Calotropis gigantea* were evaluated *In-vitro* by poison food technique (PFT) @ 3, 5, 7 and 9% concentrations against *Alternaria brassicae* causing blight of mustard. *In-Vitro* study on *A. brassicae* revealed that all five plant extracts at all four concentrations significantly inhibited the mycelial growth of this pathogen as compared to control. However *Ocimum sanctum* was found most efficacious with growth inhibition of (31.85%) followed by *E. globulus* (28.97%) and *L. camara* (23.60%).

Singh *et al.* (2013) studies the Eco-friendly management of the ten plant extracts were found effective in inhibiting the growth of the pathogen *In-vitro* and degree of inhibition varied from 33.20 to 67.60% at 5% and 48.90 to 77.80% at 10% concentration, respectively. Maximum inhibition (77.80%) was recorded with leaf extract of *Eucalyptus* sp. followed by leaf extract of *Datura* (72.20%) and bulb extract of garlic (64.40). Eucalyptus also inhibited spore germination up to 100% at both the concentration proved most fungitoxic against the pathogen, followed by *Tulsi* (92.60%) and *Garlic* (76.10%) at 10% concentration.

Mahapatra and Das (2013) observed the aqueous extract of three botanicals as leaves of Neem (*Azadirachta indica*), bulbs of Garlic (*Allium sativum*) and rhizome of Ginger (*Zingiber officinale*) at four different doses (5, 10, 15, and 20%) were evaluated against Alternaria leaf blight of mustard under field condition. The disease was adequately managed by the application of these three botanicals irrespective of their doses in comparison to untreated control.

Two years data revealed that spraying of Neem leaf extract @15% was more effective against this disease as well as increased the seed yield of mustard. Seed yield was significantly highest ($p < 0.05$) on application of Neem leaf extract @15% over other treatments (1403.83 kg/ha) where as in check had only 820.33kg/ha. Garlic bulb extract@10% also gave better yield (1366.17kg/ha) which is similar to that of 10% of Neem leaf extract (1383.00kg/ha). Cost benefit ratio was also highest (1:2.5) at 15% Neem leaf extract which was similar to that of 10% of the same botanicals (1:2.0) and 10% Garlic bulb extract (1:1.9). It is indicating that the spraying of Neem leaf extract on mustard was effective against Alternaria blight resulting superior performances in seed yield for consecutive two years.

Three botanical extracts were evaluated *In-vitro* (@ 10 and 20%) against *Alternaria brassicae*, inciting Alternaria blight of mustard (*Brassica juncea* L.). All the tested botanicals were found fungitoxic and significantly inhibited mycelial growth of *A. brassicae* over untreated control. However, percentage inhibition of the test pathogen was increased with increase in concentration of the botanicals extract. Among the botanicals evaluated, *Azadirachta indica* (Neem) was found most fungi toxic and recorded significantly highest mean growth inhibition (80.46%) of the test pathogen. The second and third best botanicals in respect of fungitoxicity were *Polyalthia longifolia* (Ashoka) and *Oscimum sanctum* (Tulsi) which recorded next best maximum mean growth inhibition, respectively of 77.76 and 71.41 per cent of the test pathogen, **(Harde and Suryawanshi 2014).**

Kumar *et al.* (2015) noticed the present investigation; three plant extracts were tested against *Alternaria brassicae* through the food poison technique at 5, 10 and 15% concentration. Among the all used treatments, Turmeric, Garlic and Neem were found superior. Maximum inhibition of the mycelium growth at 5, 10 and 15% concentration after 10 days of inoculation was found in Turmeric (53.22, 58.58 and 66.67%) followed by Garlic (47.70, 49.89 and 59.89%) and Neem (40.00, 44.36 and 49.81%), respectively.

All the extracts tested, *Eucalyptus* leaf extract showed significant reduction in radial growth, sporulation and spore germination. Under laboratory condition, leaf extracts of *Eucalyptus, Ocimum* and *Anagallis* showed maximum reduction (92.74, 91.93 and 91.53 per cent decrease over check, respectively) in radial growth whereas *Ocimum, Eucalyptus* and *Utrica* showed minimum sporulation intensity 91.66, 89.90 and 71.29 per cent, respectively. Significantly lowest reduction of spore germination was observed with *Utrica* followed with

Ocimum and *Eucalyptus* by 86.76, 79.56and 79.11 per cent, respectively. Under glasshouse condition, *Eucalyptus* spray gave significant lesser number of spot/leaf (2.05), minimum size of spot (1.28mm), minimum sporulation intensity(1.22) and minimum disease index (13.6) followed by *Calotropis*, *Ocimum* and *Polyanthai* extractspray, **(Ramezani and Abdollahi, 2015).**

Singh and Singh (2016) observed the six plant extract *viz*., Datura (*Datura stramonium*), Eucalyptus (*Eucalyptus globulous*) ,Karang (*Pongamia glabra*), Neem (*Azadirachta indica*), Madar (*Calotropis gigantean*) and Wild sage (Lantana camara) were evaluated *In-vitro* by poison food technique @ 3, 6, 9 and 12% concentrations against *Alternaria brassicae* causing blight of mustard. The results revealed that all the plant extracts inhibited the percent growth inhibition against test fungus as compared to control. However *A. indica* was found most effective with growth inhibition of (38.7%) followed by *E. globulus* (36.7%). Some extract such as *P .glabra* and *D. stramonium* showed moderate inhibition over control (30.9 and 21.6 respectively). Among all plant extract, *C. gigantean* showed least (15.3%) inhibition over control against *A. brassicae*.

Thirteen botanical extracts were significantly inhibited mycelia growth in comparison to control against *Alternaria brassicae* at both the date. Among the extract *Allium sativum* (Bulb), *Nicotiana tabacum* L., *Eucalyptus globules* L., *Parthenium hysterophorus* L. are inhibiting mycelial growth at both dates of observation. It also resulted 100% reduction growth in *Datura alba* and were significantly superior to all other tested extracts *Curcuma longa* and *Azadirachata indica* inhibited growth followed by *Lawsonia inermis* and *Lantana camara* over control observed by **(Singh *et al.*, 2017).**

Yadav *et al.* (2019) tested the extracts of 54 plants was tested their efficacy at 5% and 10% concentration (*In-vitro*). All the botanicals tested were effective showing different levels of toxicity against *Alternaria brassicae* in inhibiting the growth of pathogen significantly over control but the degree of inhibition varied from 0.00 (check) to 60.61 per cent (Garlic) at 5 per cent and 0.00 (check) to 72.21 (Garlic) at 10 per cent concentration. In this way the maximum inhibition was recorded through Garlic extracts at both the concentration tested fallowed by Eucalyptus. There was no any fungitoxicantic character in found better for the inhibitory effect against *Aloevera* the pathogens. All the 29 botanicals test extracts inhibited the spore germination of the pathogens. Garlic and Eucalyptus was most fungi toxic causing 100% inhibition at 5% and 10% concentration followed by Ashok (90.77% and 100%), Tulsi (87.44% and 100%), Datura (85.09% and 100%), Neem (82.44% and 100%), respectively.

3. Chemical Control

Hussain (1993) observed the field experiment at Regional Agricultural Research Station, Ishurdi, Bangladesh during *Rabi*, 1991-92 to find the effect of number of Rovral sprays on incidence of Altemaria blight and yield of mustard cv. Tori 7. One, two, three and four sprays were applied at 10 days interval. The highest seed yield of 1483.3 kg ha-1was obtained from four sprays which was statistically similar to that with three sprays.

Singh and Singh (2002) trials conducted in the field during 2001-02 and 2002-03 crop seasons, 3 spray of Iprodione 50 WP (Rovral @ 0.20%) followed by Mancozeb 75 WP (Indofil M-45 @0.2%) and Propineb 70 WP (Antracol @ 0.2%) gave the most effective Alternaria blight control and yield gain.

Mukherjee *et al.* (2003) studied the efficiency of Iprodione against Alternaria blight (*Alternaria brassicae*) infecting Indian mustard cv. Pusa Bold in New Delhi, India during 1998-2000. Iprodione was sprayed to plants at 500g a.i./ha during the early pod stage. Iprodione was more effective than Mancozeb in the reduction of Alternaria blight incidence. The increase in Indian mustard yield in Iprodione treated plots was higher by 24-59% than that in the control plots.

Singh and Singh (2006) observed that three consecutive sprays of Mancozeb resulted in maximum control of Alternaria leaf blight intensity followed by schedule with two consecutive sprays of Mancozeb (0.2%) and third of Ridomil–MZ (0.25%).foliar sprays of Mancozeb have been found most effective in disease management.

Singh *et al.* (2006) noticed the, six seed dressing fungicides *viz.* ,Metalaxyl, Carbendazim, Mancozeb, Thiophanate-methyl, Iprodione and BAS 38601 F, in combination with spray of Mancozeb (0.25%) were tested for the control of foliar diseases, Alternaria leaf spot (*Alternaria brassicae*) of Indian mustard. All the seed treatments improved germination and reduced disease intensity. Seed treatment with Mancozeb and spray of the same fungicide was most effective against Alternaria leaf spot controlling up to 58.8 to 74.7% disease. The highest yield was recorded with Iprodione (16.0-17.36 q/ha) and Mancozeb (26.0-31.12 q/ha),

Khan *et al.* (2007a) tested as three systemic fungicide Thiophanate methyl, Ridomil-MZ (Mancozeb, 64% + Metalaxyl, 8%) and Carbendazim alone and in combination with four non systemic fungicides Captan, Mancozeb, Zineb and

Thiram in the field at 0.2% a.i.L^{-1}. Ridomil-MZ was most effective followed by the combination of Carbendazim + Captan.

Kumar *et al.* (2009) found that Iprobenfos @ 0.1 per cent and Propiconazole @ 0.05-0.1 per cent were also found effective against Alternaria blight in case of Indian mustard under field condition at Kumarganj, Faizabad.

Harde and Atar (2014) observed the bio-efficacy of some fungicides was evaluated *In-vitro* against *Alternaria brassicae*. All the tested fungicides were found fungistatic/fungicidal against the test pathogen and significantly inhibited mycelial growth of the test pathogen over untreated control. Among the tested fungicides the Iprodione 50 WP was found most effective and recorded significantly highest mean mycelial growth inhibition (100.00%). The second and third best fungicides found were Mancozeb 75WP and Carbendazim 50 WP which recorded mean growth inhibition, respectively of 90.29 and 88.58 per cent. This was followed by the fungicides, *viz.*, Chlorothalonil 75 WP (inhibition: 86.70%), Copper-oxychloride 50 WP (inhibition: 86.60%), Difenconazole 25 EC (inhibition: 78.37%), Hexaconazole 5 EC (inhibition: 75.65%) and Penconazole 25 EC (inhibition: 72.18%).

Jackson and Kumar (2019) tested the different fungicides *In-vitro* and *In-vivo* condition *viz.*, Azoxystrobin 23% SC (Amistar), Propiconazole 25% EC (Tilt), Mancozeb 75% (Indofil M-45) and combined formulation of Carbendazim 12% +Mancozeb 63% (Colt). Tilt proved best in lab conditions, showing complete inhibition of the test pathogen at all concentrations. Amistar gave best performance among all test chemical fungicides under field conditions with lowest severity of 36.30%, showing lowest AUDPC of 458.33 and infection rate 0.0266 unit-days. All the treatments improved the growth and yield of the crop significantly, with highest yield being recorded in treatment of Amistar (2536.21 kg/ha).

Kumar *et al.* (2024) observed the bio-efficacy of some fungicides was evaluated *In-vitro* at three concentrations *viz.*, 100, 150 and 200ppm against mycelial growth of *Alternaria brassicae*. Among these fungicides it was observed that Propiconazole 25% EC, Propineb 70% WP and Carbendazim 12% combined with Mancozeb 63% WP was got 100% percent mycelial growth inhibition of *Alternaria brassicae In-vitro* at all three concentrations with comparison to control.

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SOCIO-ECONOMIC IMPORTANCE OF LINSEED AND INTEGRATED MANAGEMENT AGAINST WILT DISEASE

Abstract

Flax (Linum usitassimum L.) belongs to the family Linaceae and also known as flax, which is one of the oldest cultivated shops. still, it's generally accepted that flax began in an area east of the Mediterranean towards India. The use of flax filaments for the manufacture of fabrics in Northern Europe dates back to the Neolithic(New Stone Age). Of all cloth filaments, flax filaments are one of the most natural and terrain friendly filaments. Following symptoms of linseed wilt caused by Fusarium oxysporum f.sp. lini. Plants showed wilting at all stages of their growth. At seedling stage, leaves and stems drooped with yellowing symptoms and plant dies out quickly. In very late appearance of disease i.e. after capsule formation, premature ripening of the plants was observed. Transverse section of roots and lower part of the stem showed the presence of fungal mycelium in the vascular tissues which chocked vascular vessles and blocking, browning resulting in the wilting of the plants. linseed wilt is caused by the seed-borne and soil-borne fungus Fusarium oxysporum f.sp. lini. The fungus penetrates the plants through their roots and continues to grow within the water-conducting tissues, which disrupts water absorption and is worsened in warm weather.

Keyword: Linseed, Economic importance, Wilt, Fusarium oxysporum f.sp. lini & Management.

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I. INTRODUCTION

Flax (Linum usitassimum L.) belongs to the family Linaceae and also known as flax, which is one of the oldest cultivated shops. Still, it's generally accepted that flax began in an area east of the Mediterranean towards India (Zeven and Zhukovsky, 1975) and was presumably tamed there for the first time. The general name Linum is deduced from the Celtic word lin for thread and the species name usitatissimum given by Carl Linnaeus. So it's directly related to its colorful uses and its significance in ancient times. It's one of the oldest oil painting seeds known as poor man’s factory in India. It has a special meaning among the oilseeds in Rabi and is also called" Alsi" in India, also under the original names" Tisi"," Mosina" and" Arise". Flax is one of the first species of cultivated shops. The ancestor of small- seeded flax is L. bienne which comes from Kurdistan and Iran, while a separate species of L. bienne with high oil painting content and high seed weight is the parent of flax that originates on. it applies to the Mediterranean region(Murre, 1955).

The use of flax filaments for the manufacture of fabrics in Northern Europe dates back to the Neolithic (New Stone Age). Of all cloth filaments, flax filaments are one of the most natural and terrain friendly filaments. Linen fiber fabrics called Lilen' or Lins of fabrics', in which the stylish rates of linen filaments are used to make suits, shirts, bedsheets, cloth lace, damasks, curtains, etc., blended fibre shows better quality as jute or cotton fabrics in chance (Pandey and Dayal, 2003). Due to the advanced attention of health- promoting omega- 3 adipose acids (nascence linolenic acid), which lowers cholesterol and offers cardiovascular benefits, numerous flaxseed- grounded formulas have been formalized. The ground seeds flours are used for value creation and for the product of colorful nutritive food medications (Chauhan *et al.*, 2009). Flaxseed oil painting cutlet is one of the stylish nitrogen diseases among oil painting galettes in terms of nitrogen, phosphorus and potassium (4.7 N, 11.7 P_2O_5, 1.3 K_2O) to the soil (Anonymous, 2011).

Nutritive composition, among functional foods, flaxseed has been shown to be a implicit functional food that's a good source of nascence- linolenic acid, lignans, high- quality protein, answerable fiber, and phenolic composites (Oomah 2001).

Regular civilization of flax seeds in the same field leads to soil borne conditions, which lead to a high proportion of conditions. The magnitude of the damage largely depends on the timing of the attack. The crop is known to suffer from a number of fungal, bacterial, viral and nematodal conditions. The lists of important complaint are given in table below. Diseases of Linseed Reported from India.

Diseases	Causal Organism	References
Fungal		
Rust	*Melampsora lini*	Butler (1914, 1918), Pearl (1923), Prasad (1940), Chowdhury (1951), Hora (1961).
Wilt	*Fusarium oxysporum* f.sp. *lini*	Butler (1918), Pearl (1924), Verma (1945), Merh and Kulkarni (1961), Sharma *et al.* (1971).
Powdery mildew	*Oidium lini*	Padwick (1941), Mundkur and Ahmed (1946), Patel *et al.* (1949), Porwal (1964), Pavgi and Singh (1965), Sandhu and Chandwani (1965), Shukla and Pathak (1967).
Alternaria blight	*Alternaria alternata*	Dey (1933), Arya and Prasad (1952), Kalia *et al.* (1965), Singh *et al.* (1974).
	A. lini	Khanna and Chandra (1981), Kumar *et al.* (1985).
	Alternaria sp.	Mc Rae (1929).
	A. brassicae	Arya and Prasad (1953).
Cercospora leaf spot	*Cercospora lini*	Rathaiah and Pavgi (1971).
Macrophomina stem rot	*Macrophomina phaseolina*	Sunderraman (1931), Uppal (1935).
	Rhizoctonia sp.	Asthana (1957).
	Rhizoctonia bataticola	Bedi *et al.* (1961).
Stem/Collar rot	*Sclerotium rolfsii*	Khatti *et al.* (1980).
Viral		
Leaf curl	Tobacco leaf curl virus	Vasudeva (1958).
Nematodes		
Root knot	*Meloidogyne incognita*	Prasad and Khan (1990).
	M. hapla	Chhabra (1992).

	M. triticorhiza	Gaur and Sharma (1999).
Lesion nematodes	*Pratylenchus* sp.	Prasad and Khan (1990).
	Rhotylenchus reniformis	Swarup *et al.(*1967), Nath *et al.(*1969).
	Tylenchorhynchus brevidens	Sethi and Swarup (1968).

The wilt diseases of linseed are considered to be the major factors responsible for reducing the production, productivity and quality of seed.

1. Symptoms

Following symptoms of linseed wilt is caused by *Fusarium oxysporum* f.sp. *lini*. Plants showed wilting at all stages of their growth. At seedling stage, leaves and stems drooped with yellowing symptoms and plant dies out quickly. In very late appearance of disease i.e. after capsule formation, premature ripening of the plants was observed. Transverse section of roots and lower part of the stem showed the presence of fungal mycelium in the vascular tissues which chocked vascular vessles and blocking, browning resulting in the wilting of the plants.

Singh (1986) observed that transverse sections of roots and lower part of the stem of wilted plants of linseed showed the presence of fungus mycelium in the vascular tissues which turn brown. The dead plants usually do not fall down but remain standing as dry and defoliated stems. If the disease appears very late i.e., after pod formation, the only symptom is the premature ripening of the plants.

Sweet *et al.*, (1991) reported that the symptoms of the Fusarium wilt in linseed are drooping followed by death of upper leaves and growing point The leaves of affected plant turn brown and whole plant eventually senesces prematurely. They also noted that infection causes reduction in oil yield.

Singh *et al.*, (2017) stated that the pathogen may attack linseed plants at any stage from seedling to maturity. The young seedlings are affected almost three weeks after sowing when atmospheric temperature is generally high. The cotyledons of the affected seedlings turn dull coloured and the edges roll inward. The base of hypocotyls shows a constricted appearance. The young seedlings collapse from this point and ultimately die-off. In the older plants the disease appears as small ill defined dark green patches on the leaves. Later the leaves shrivel, branches droop and ultimately the plants die-off, although they remain standing. Sometimes partial wilting is also observed in which the affected part turns brown while other side remains green. On splitting of infected basal stem and roots, the brownish discoloration of vascular tissues is observed. The mycelium of the pathogen is found in abundance in the infected discolored vascular tissues.

Thind (1998) noted that plants are susceptible to attacks at all growth stages. The edges of infected cotyledons in young seedlings curl inwards, halting the plant's growth and leading to seedling death.

Saharan *et al.* (2005) found that symptoms of wilt diseases can differ even within the same host, influenced by the infection stage and environmental conditions. *Fusarium oxysporum* typically causes symptoms such as root rot, stem rot, and sclerotium rot. In older plants, leaves may shrivel, branches may sag, and the plant may ultimately die while still standing. Occasionally, the stem of affected plants may brown on one side while the other side remains green.

Kumar *et al.* (2014) described the disease as manifesting through the rolling and wilting of cotyledons at the seedling stage, resulting in the collapse of young seedlings. In mature plants, dark green to brown patches form on the leaves, which then shrivel, leading to drooping symptoms from the tips of the plants, along with drying of leaves and stems, and discoloration of the vascular tissues, resembling symptoms associated with wilt caused by *Fusarium oxysporum* f.sp. *lini*.

II. MORPHOLOGICAL CHARACTERISTICS

The *Fusarium oxysporum* f.sp. *lini* was recognized based on its cultural and morphological traits. The mycelium displays a white cottony growth, and the conidiophores are septate, dark brown at the base, and exhibit characteristic knee-bends. Three types of conidia are formed: micro-conidia, macro-conidia, and chlamydospores.

Microconidia: These are hyaline, small, elliptical or curved, and can be single-celled or two-celled.

Macroconidia: These are also hyaline, thin-walled, linear, curved or fusoid, with pointed ends and contain 3-4 septa.

Chlamydospores: The fungus produces thick-walled, spherical or oval chlamydospores, which can be terminal or intercalary, found singly or in chains of 2 to 3.

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Gill (1987) reported that in *Fusarium oxysporum* f.sp. *lini*, the mycelium is septate, branched, and creates stroma of various shades. The conidiophores are branched and form sporodochia. The measurements for micro and macro-conidia range from 4.8-14.4 x 2.2-4.8 µm and 21.0-53.0 x 2.4-5.6 µm, respectively.

Saharan *et al.* (2005) indicated that the morphological features of this fungus resemble those of other wilt-causing fungi in the *Fusarium* genus. The mycelium is septate, branched, intra-cellular, and forms stroma of various shades. The conidiophores are branched and develop in sporodochia, occasionally reducing pinnotes or directly arising from the mycelium. The conidia are hyaline and mostly contain 1-2 cells. Both micro and macroconidia are generated by the pathogen, with measurements for microconidia at 4.8-14.4 × 2.2-4.8 µm and for macroconidia at 21.0-53.0 × 2.4-5.6 µm. Conidiophores are typically short and branched, often forming in erumpent sporodochia, with the conidia being fusiform to falcate, 3-septate, and appearing hyaline to light pink in mass, while microconidia are not abundant.

Somesh *et al.* (2019) isolated the pathogen from roots affected by wilt. The isolated pathogen was identified based on its morphological and cultural characteristics, as well as its pathogenic behavior toward the host. The presence of white fluffy colonies of *Fusarium oxysporum* f.sp. *lini* was identified using microscopy to observe its morphological characteristics. The mycelium was septate, branched, and intracelluar, developing into thin stroma. The colony appeared white to very pink and velvety. Conidiospores were short and branched, typically forming erumpent cream-colored sporodochia. Microconidia were hyaline to brownish-white, oval to ellipsoid, and produced abundantly in culture, measuring 4.8 - 14.4 × 2.2 – 4.8 µm. Macroconidia were elongated, fusiform, falcate to cylindrical, 3 to 5 septate, measuring 21.0 – 41 × 2.4

1. Reported

The Fusarium wilt disease affecting linseed was first identified in the world by **Luggar in 1890** in Minnesota, USA. In India, Rae provided the initial report of this disease in 1926 from Madhya Pradesh. Fusarium is a fungus that resides in the soil and is responsible for causing wilt in various crops. In many instances, the specific fungus responsible for wilt in a given crop is unique to that crop. Regarding linseed, Bolley reported in 1901 that the wilt is caused by Fusarium lini. Later, in 1940, Synder and Hansen reclassified the fungus causing linseed wilt as Fusarium oxysporum f.sp. lini.

2. Spread

Anonymous (1999) linseed wilt is caused by the seed-borne and soil-borne fungus *Fusarium oxysporum* f.sp. *lini* (Bolley). The fungus penetrates the plants through their roots and continues to grow within the water-conducting tissues, which disrupts water absorption and is worsened in warm weather.

Saharan and Mehta (2002) noted that the optimal temperature for the pathogen's growth in the soil is between 24-28°C, although it can endure a broad range of temperatures from 14-38°C.

Souramma and Singh (2004) discovered that a pH level of 6.5 is most conducive to the growth and sporulation of *Fusarium oxysporum* f.sp. *lini*. They also indicated that the in vitro temperature range of 25-30°C and a pH of 5-7.5 are ideal for the growth of *F. oxysporum* f.sp. *lini* affecting the linseed crop.

3. Survey

Bhima *et al.* (2016) conducted a disease survey on linseed in Mayurbhanj, Odisha, from 2000-2001 to 2008-2009 over nine years. The incidence rates for wilt, Alternaria blight, powdery mildew, and rust varied from nil to 7.6%, nil to 80.0%, nil to 20.0%, and nil to 32.7%, respectively, throughout these years. Plant pathology research initiatives and resistance breeding should be implemented to counteract Alternaria blight disease in order to maintain linseed productivity.

Pearl (1923) provided the first report of the disease in India from Madhya Pradesh state.

Marlatt (1952) gathered diseased flax plants from Yuma Valley in Arizona, USA, where a wilt spot was noticed in a field, and isolated *F. oxysporum* f.sp. *lini* (Bolley) from the diseased area of the plant's stem.

Singh and Singh (1970) rust and *fusarium* wilt have historically been the key factors limiting flax production in most flax-growing regions globally. Early in the twentieth century, fusarium wilt was acknowledged as the predominant disease issue in flax, particularly in North America, where susceptible varieties were cultivated.

Kumar *et al.* (2014) conducted a survey to assess the occurrence and distribution of linseed wilt in Kanpur. The highest incidence, recorded at Gopalpur (Bithoor), was 9%, followed by Aliapur (Ghatampur). In fields where linseed had not been previously cultivated, the overall wilt percentage ranged from 0 to 9 percent, while in fields already affected by wilt, it ranged from 10 to 37 percent.

Singh and Singh (2021) carried out a survey on the incidence of linseed diseases across five districts in Eastern Uttar Pradesh during the 2018-2019 to 2019-2020 period. One Tehsil was selected from each of the five districts, which included Jaunpur, Varanasi, Mirzapur, Chandauli, and Azamgarh. Three villages were chosen in each district, with three farmers' fields recorded separately for data collection. Varanasi exhibited severe infection with the highest average PDI of 51.10%, followed closely by Chandauli at 51%, Mirzapur at 49.18%, Azamgarh at 49.06%, and the lowest average PDI of 45.92% in Jaunpur for the year 2018-19. In the following year, 2019-2020, Azamgarh emerged as the most affected district, showing an average PDI of 51.11%, with Jaunpur at 48.96%, Varanasi at 47.88%, Mirzapur at 46.62%, and the minimum average PDI of 45.86% in Chandauli.

Sharma *et al.* (2005) evaluated various culture media for growth analysis, determining that linseed meal and maize meal media are the most effective for promoting the growth and sporulation of the pathogen among ten different media.

Mulekar *et al.* (2017) examined morphological variability among 24 isolates of *Fusarium oxysporum* f. sp. *ricini*, the causal agent of wilt in castor, collected from different geographic regions of India. They grew the isolates in three liquid media: Potato Dextrose, Richard’s, and Czapek’s medium. The average length and width of microconidia ranged from 7.23 µm (For-20) to 9.47 µm (For-4) in Potato dextrose broth, 7.13 µm (For-10) to 10.33 µm (For-23) in Richard’s broth, and 6.40 µm (For-10) to 9.69 µm (For-4) in Czapek’s broth. Similarly, the average length and breadth of macroconidia varied from 12.32 µm (For-15) to 34.56 µm (For-2) in Potato dextrose broth, from 13.62 µm (For-6) to 22.81 µm (For-2) in Richard’s broth, and from 14.72 µm (For-1) to 30.56 µm (For-2) in Czapek’s broth.

Patra and Biswas (2017) investigated eleven isolates of *Fusarium oxysporum* f. *ciceri* for their cultural, morphological, and pathogenic variability. The radial growth of isolates varied from 72 mm to 87 mm seven days post-inoculation on

PDA medium. The size of macroconidia ranged from 13-15 x 2-3 µm to 15-19 x 3-4 µm, while microconidia measured from 3-4 x 1-2 µm to 5-6 x 2-3 µm. The majority of macroconidia had a sickle shape, and microconidia were predominantly round to oval. Most isolates exhibited high pathogenicity.

Sangava *et al.* (2018) studied the cultural and morphological variability in five isolates of Fusarium oxysporum f. sp. ricini collected from various castor-growing regions of Gujarat. Each isolate displayed notable differences in cultural characteristics, mycelial color, pigmentation, sporulation, and the size of microconidia and macroconidia. Various media such as Rose Bengal medium, Potato dextrose medium, Richard's medium, Asthana and Hawker's medium, and Glucose asparagine medium were employed to examine the fungi. These findings will be beneficial for the development of Fusarium wilt-resistant castor hybrids and varieties.

4. Isolation

To isolate Fusarium wilt, infected linseed stems were chopped into pieces, and tissue squares approximately 0.5 cm in size were extracted from the advancing margins of lesions. These were immersed in a 0.1 percent Mercuric Chloride solution for 30 seconds, followed by 2-3 washes with sterile water. Excess moisture was removed using blotting paper. Subsequently, small pieces were transferred into hardened Potato Dextrose Agar (PDA) medium using sterilized forceps. Petri dishes were labeled appropriately with a glass marker and incubated at 26±10°C in a B.O.D. incubator. After two days, fungal growth was observed in the petri plates. This was further purified using the hyphal tip method. The cultures were then preserved on PDA slants for subsequent analysis.

Wagh *et al.*, (2010) conducted an experiment to examine variability among six isolates of Fusarium oxysporum f.sp. lini. Pure cultures of the six isolates (Fol-1 to Fol-6) were generated to assess variations in morphological characteristics (size and shape of macroconidia and microconidia), colony diameter, and culture traits. Isolate Fol-6 exhibited rapid growth (82 mm), whereas the other isolates demonstrated moderate mycelial growth ranging from 71.6 mm to 78.7 mm. The minimum average length was recorded in isolate Fol-5, while the maximum average length was found in isolate Fol-1. Isolates Fol-2 and Fol-5 produced a significant number of microconidia, while the other isolates yielded fewer microconidia. The variability in the pathogenicity of Fusarium oxysporum f.sp. lini isolates was assessed using two methods: soil infestation method and test tube method.

5. Pathogenicity

The purification of fungal isolates was performed using the single spore isolation technique **(Choi, 1999).**

Kumar *et al.*, (2017) carried out pathogenicity tests on isolates from infected linseed roots on the same host to verify the fungus's pathogenic characteristics. The inoculum was created by cultivating the pure culture of Fusarium oxysporum f.sp. lini in a sand corn meal (9:1) medium within 250 ml conical flasks, which were autoclaved at 15 p.s.i. for 30 minutes. This culture was mixed into the soil at a rate of 5 percent relative to the soil weight in the pots. The pots were maintained in a greenhouse and were closely monitored for seedling emergence and wilt symptoms for up to 60 days after sowing. Following germination, plants were checked daily for symptom development to confirm Koch's postulates.

Somesh *et al.*, (2019) also conducted pathogenicity tests on isolates derived from affected linseed roots on the same host to affirm the fungus's pathogenicity. This experiment was performed in pots filled with roughly 5 kg of sterilized soil. The inoculum was prepared by growing the pure culture of the fungus in a sand corn meal (9:1) medium in 250 ml conical flasks. Each flask was then inoculated with pure culture of F. oxysporum f.sp. lini. The soil inoculation occurred seven days prior to sowing by thoroughly mixing the soil with the fungal culture. The pots were maintained in a greenhouse and were meticulously observed for seedling emergence and wilt symptoms to confirm Koch's postulates.

Singh *et al.* (2017) successfully isolated Fusarium oxysporum f. sp. ciceri from both culture media and natural hosts, and they purified it and confirmed its pathogenicity in pot culture as well as on potato-dextrose-agar medium. The pathogenicity test was conducted using the chickpea variety Radhey, which displayed wilting symptoms 25 days post-inoculation. Out of 75 seeds, 68 germinated under infected conditions. Symptoms appeared in 20 plants during the seedling stage, 14 plants in the adult stage, while 34 plants did not exhibit any wilting symptoms.

6. Epidemiology

Saharan and Mehta (2002) noted that the optimal temperature range for the pathogen's growth in soil is 24-28°C, although it can survive across a broad range of 14-38°C. Souramma and Singh (2004) determined that a pH level of 6.5 is most favorable for the growth and sporulation of Fusarium oxysporum f. sp. lini. They also indicated that the in vitro temperature range of 25-30°C and a pH range of 5-7.5 are ideal for the growth of F. oxysporum f. sp. lini, which causes wilt in linseed crops.

7. Survival

Fusarium oxysporum f. sp. *lini* acts as a facultative parasite, capable of surviving on organic matter in the soil for many years, producing conidia and chlamydospores, and attacking flax plants when cultivated in the same soil. Additionally, the fungus can spread by adhering to the surface of flax seeds, or as noted by Hiura (50), the hyphae can penetrate the seed coats and remain dormant until they infect the seedlings during germination.

Yadav *et al.* (2019) reported that *fusarium* root and stem rot is among the most destructive diseases affecting greenhouse cucumber. The pathogen responsible, *Fusarium oxysporum* f. sp. *radicis cucumerinum*, is prevalent in cucumber-growing regions, leading to significant economic losses. A brief review of the importance and variability of different isolates is provided below.

Pal et al. (2019) conducted an in vitro experiment to determine the optimal temperature and pH for the growth and sporulation of *Fusarium oxysporum* f. sp. *lini*. The study found that after 9 days of incubation, the fungus exhibited maximum growth of 88.33 mm at 24°C, with a peak growth rate of 9.81 mm per day and the highest sporulation of 7.9X10^6 per ml. In terms of pH, the fungus reached a maximum growth of 86.33 mm at pH 5.5, with a highest growth rate of 9.59 mm per day and the maximum sporulation of 8.2X10^6 per ml after 9 days of incubation at 25±20°C.

III. CULTURAL PRACTICES

Kishore et al. (2008) investigated the impact of soil solarization and sowing dates on wilt disease in linseed caused by *Fusarium oxysporum* f.sp. *lini*. They found an average wilt incidence reduction of 58% after four weeks of soil solarization, followed by reductions of 41.0%, 25.5%, and 18.5% after three, two, and one week(s), respectively. The yield increased incrementally by 109.0%, 66.9%, 58.0%, and 18.4% for those same time periods. The disease occurrence was significantly affected by the timing of planting, with the highest wilt incidence of 70% noted on October 20, which decreased in subsequent sowing dates, reaching a low of 34.0% on December 10. However, the maximum yield of 661.0 kg per hectare was observed on November 20, which was statistically comparable to the crops sown on November 10 and November 30.

Rajput *et al.* (2018) carried out a field trial to assess the influence of a non-host based intercropping system of linseed (*Linum usitatissimum* L.) and chickpea (*Cicer arietinum* L.) on the incidence of linseed wilt caused by *Fusarium oxysporum* f.sp. *lini*. They tested two linseed varieties: Shekhar (susceptible, V2) and RLC-92 (moderately resistant, V1) intercropped with a non-host chickpea variety, ‘Vaibhav’, in various row ratios. Among the two varieties, RLC-92 exhibited the least disease incidence at 8.04%, while Shekhar showed the highest incidence at 78.99%. In the intercropping system, the lowest disease incidence was recorded in a 2:1 (linseed: chickpea) row arrangement for both varieties, V1 (8.04%) and V2 (58.53%).

Sharma and Goswami (2010) conducted a field experiment at the Agriculture Farm AS College in Lakhaoti, Bulandshahr (UP) during the Rabi seasons of 2006-07 and 2007-08 to examine the net profit from a chickpea + linseed intercropping system. They studied five intercropping systems: chickpea sole at 45 cm spacing, linseed sole at 45 cm spacing, and chickpea + linseed in 3:1, 4:1, and 6:2 ratios. The treatments were arranged in a split plot design and replicated four times, with the 4:1 intercropping system found to be the most advantageous for net profit. The chickpea + linseed 4:1 system yielded the highest net profits of Rs. 15285/ha and Rs. 13540/ha, with benefit-cost ratios of 1.31 and 1.01 during the years 2006-07 and 2007-08.

1. Fertilizer

Singh *et al.* (2013) performed a field experiment at Banaras Hindu University, Varanasi during the winter (Rabi) season of 2009–10 to assess the performance of linseed (*Linum usitatissimum* L.) varieties affected by varying NPK and S levels in irrigated sandy clay loam soil. The trial consisted of three NPK levels (60, 30, 30; 90, 45, 45; and 120, 60, 60 kg NPK/ha) arranged in main plots, alongside three levels of sulphur (0, 20, and 40 kg S/ha) and two varieties (Garima and Shekhar) in sub plots, replicated three times under a split plot design. Results indicated that applying 90-45-45 kg NPK/ha significantly enhanced growth metrics such as plant height, number of primary and secondary branches per plant, dry matter accumulation, yield characteristics, and seed yield compared to 60-30-30 kg NPK/ha.

In a study **by Gaikwad *et al.* (2020)**, a field experiment was carried out during the Rabi season of 2016-2017 on vertisol at the Oilseed Research Station in Latur to evaluate how linseed varieties respond to various spacing and fertilizer levels. The experiment included eighteen treatment combinations, featuring two varieties: NL-260 (V1) and LSL-93 (V2), with three fertilizer levels, namely 50% RDF (F1), 100% RDF (F2), and 150% RDF (F3), all replicated twice. The recommended fertilizer dose (RDF) was 60:30:00 NPK kg ha-1. The findings revealed that the growth and yield-related attributes of linseed, such as the number of branches per plant, plant spread, total dry matter per plant, number of capsules per plant, capsule weight, number of seeds per capsule, seed yield per plant, and test weight (g), were significantly enhanced by the variety LSL-93 (V2), apart from plant height, straw yield, and biological yield (kg ha-1). The variety LSL-93 (V2) exhibited a significantly greater ability to produce higher seed yield, oil yield (kg ha-1), gross margin return (GMR), net margin return (NMR), and benefit-to-cost (B:C) ratio in comparison to the variety NL-260 (V1). Regarding the different spacing, a spacing of 30 cm × 10 cm (S3) resulted in significantly better growth and yield attributes compared to the 30 cm × 5 cm (S1), and it was found to be similar to the 45 cm × 5 cm (S2). The closer spacing of 30 cm × 5 cm (S1) yielded the highest seed yield, oil yield, straw yield, GMR, NMR, and B:C ratio.

For managing diseases, altering the date of sowing is considered the most cost-effective and efficient disease control method. The objective was to determine the optimal sowing date for managing wilt in linseed.

In research conducted by **Kannaiyan *et al.* (1975),** trials involving 12 lentil cultivars in Uttar Pradesh, sown on five dates spaced 15 days apart from October 15 to December 15, resulted in *Fusarium oxysporum* f.sp. *lentis* seedling infection rates of 8.7%, 2.8%, 5.3%, 0.8%, and 0.7%, with average seed yields of 2.48, 2.54, 2.65, 1.73, and 1.5 t/ha, respectively; late-stage infection ranged from 0.2% to 1.3%.

Kishore *et al.* (2008) conducted a trial to evaluate the impact of sowing dates on wilt incidence in linseed, finding that disease incidence was significantly affected by planting dates. The highest wilt incidence was observed on October

20 (70.0%), which decreased with subsequent sowing dates, reaching a minimum of 34.2% on December 10. However, the highest yield (66.10 kg/ha) was obtained from the crop sown on November 20, which was statistically comparable to those sown on November 10 and November 30.

Somesh *et al.* (2019) conducted field experiments during the 2016-2017 period to manage wilt in linseed (*Linum usitatissimum* L.). The linseed cultivar Chambal was planted on seven different dates from October 10, 2017, to December 9, 2017, at intervals of ten days. The highest wilting rate of 66.66 percent occurred in the first sowing date (10-10-2017), which decreased with later sowing, with the lowest rate of 14.31 percent recorded in the crop sown in December (09-12-2017). A significant difference in wilting percentages was observed across the crops planted on different dates. The maximum yield of 582.95 kg/ha was recorded for the crop sown on 19-11-2017, followed by the crop sown on 09-11-2017 (434.81 kg/ha) and 30-10-2017 (414.81 kg/ha).

2. Resistance

Andruszewska (1998) researched the resistance of 56 linseed cultivars to Fusarium wilt during the years 1980-1990. It was determined that 24 cultivars exhibited resistance, while 20 were found to be susceptible. The cultivars AC Linora, Mikael, Summit, M-3266, and Taragui showed very high resistance, whereas Barbara, Liflora, Istru, Buchara yellow, and Abisynian were very susceptible.

Andruszewska (2005) assessed the horizontal resistance of various linseed cultivars to Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lini* in Poland. A total of 22 linseed cultivars were identified as resistant. Among these, AC Emerson, Koto, Atalante, Symphonia, Lucz, Astorga L-391, Gold Merchant, Summit, Taragui, and Mikael had high resistance to the disease.

Kishore *et al.* (2011) investigated 78 germplasm samples collected from the linseed P.C. Unit, scrutinizing them in a highly wilt-affected area of Nawabganj Research Farm, C.S.A. University of Agriculture & Technology, Kanpur, during the cropping seasons of 2003-04 and 2004-05 against *Fusarium oxysporum* f.sp. *lini*. Out of 76 tested germplasms, 26 including Ayogi, BAU-9906, BAU-2K-14, BAU-2K-15, DPL-19, EC-41656, 12BJP, Local, Jeevan, KI-1, KI-31, L-103, L-107, LC-2057, M-3, NL-14, No-7, NP (RR)-65, RLC-46, JLS-9, Padmini, Rashmi, R-552, Surabhi, Sweta, and T-397 were found resistant, while 23 were moderately resistant, 9 moderately susceptible, 14 susceptible, and 6 genotypes were highly susceptible.

Kumar *et al.* (2017) screened the reaction of genotypes against fungus and found that out of 200 genotypes examined, three lines namely LCK-6028, PKDL-71, and T-397 demonstrated no wilting (0.00%) in both years of testing and were classified as highly resistant. Additionally, 2 genotypes, SLS-58 and NDL-2004-5, exhibited less than 5% wilting and were rated as resistant (R). Twelve genotypes, including Kiran, LMS-23-06, BAU-610-A, Polf-19, H-15, BAU-2K-20, NL-165, BAU-04-07, PKDL-58, NDL-05, LMS-95-4, and RKD-1, showed less than 15% wilting and were categorized as moderately resistant. Furthermore, 41 lines were assessed as moderately susceptible, 38 as susceptible, and 104 as highly susceptible.

Tadesse *et al.* (2010) undertook an investigation on 81 geographically diverse Ethiopian accessions of linseed. These accessions were evaluated at the Agricultural Research Center in Sinana, as well as on farmers' fields in the Bale highlands of Ethiopia during the 2001-2002 cropping season. The accessions exhibited significant differences for all traits under investigation at both locations. However, there were no significant genotypic differences noted for the number of primary branches, number of capsules per plant, number of seeds per capsule, seed yield per plant, biomass, and percent oil content in the combined analysis across locations. The estimates of genotypic and phenotypic coefficients of variability at the two locations revealed significant variability for most of the studied traits.

Bio-Pesticide:

Singh *et al.* (2014) examined 50 different plant species that displayed varying levels of toxicity. Among these, the leaf extracts of Xanthium strumanium (Kanghi) and Tribulus terrestris (Gokhru) demonstrated the highest toxicity, inhibiting mycelial growth of the fungus by 81.18% and 77.66%, respectively. The other plants also showed different degrees of inhibition, ranging from 10.55% to 65.74% when compared to the untreated control.

Singh *et al.* (2015) extracted essential oils from ten Angiosperm plant species, including herbs, shrubs, and trees, using the Clevenger Hydrodistillation method. They screened three different concentrations of oil (250 mg/ml, 500 mg/ml, and 1000 mg/ml) against the linseed wilt pathogen (*Fusarium oxysporum* f. sp. *lini*), and all proved effective in inhibiting pathogen growth in vitro. The inhibition percentage generally increased with higher oil concentrations. At a concentration of 1000 mg/ml, the essential oils from *Azadirachta indica* and Cymbopogon jwarancusa completely halted fungal growth. The oils from Hyptis suaveolense, Majorana hortensis, and Nepeta hindostana inhibited pathogen growth by over 90%, while the other five species—Eucalyptus citriodora, Mentha piperita, Murraya koenigii, Ocimum basilicum, and Vetiveria zizaniodes—showed an inhibition range of 77-85% against the fungus. All of these oils can be utilized as eco-friendly measures to manage wilt disease.

3. Panchgavya

Kumar *et al.* (2020) explain that Panchagavya is a term in Ayurveda that refers to five essential substances derived from cows: urine, dung, milk, ghee, and curd. Many individuals use Panchagavya in various rituals (puja) as well as for medicinal uses. Historically, it has been part of traditional Indian rituals and is also recognized as a Cowpathy treatment, highlighting the significance of cow-based products in Ayurvedic medicine and their religious importance to Hindus.

Ashlesha and Paul, Y.S. (2014) evaluated five organic inputs—panchgavya, vermiwash, biosol, cow urine, and buttermilk—against primary pathogens affecting bell pepper, including *Colletotrichum capsici*, *Phytophthora nicotianae, Sclerotium rolfsii, Fusarium solani, Fusarium oxysporum f.sp. capsici, Sclerotinia sclerotiorum, and Rhizoctonia solani,* under both in vitro and in vivo conditions.

Chandrakanth *et al.* (2018) suggest that ancient Indian literature, including Varahamihira's 'Brihath Samhitha', Chavundaraya's 'Lokopakara', and Sarangadhara's 'Sarangadhara Samhitha', offers advice for a holistic approach to managing crop pests and diseases through the management of soil, seed, plant, and environmental factors. It is recommended to treat seeds with substances such as cow dung, milk, plant juices, and cow ghee. As a preventive strategy for disease control, the use of incense made from plant leaves and flowers, along with fish meat, turmeric, and mustard, has been noted. The use of 'Panchagavya' for disease control has proven effective in managing soil-borne diseases in tomato as well as Panama wilt disease in banana.

4. Soil Amendments

Dubey and Singh (2018) conducted tests on Neem cake, mustard cake, linseed oil cake, sawdust, and Parthenium compost, which were individually mixed into sterilized soil-filled pots two weeks before sowing. The highest level of disease control (42.85%) was achieved with neem cake, followed by mustard (38.23%), Parthenium (32.90%), linseed (28.57%), and sawdust, which showed a reduction in wilt control (23.66%) during the 2016-17 season.

Pitambar *et al.* (2010) studied four oilseed cakes—linseed cake, groundnut cake, neem seed cake, and cottonseed cake—at concentrations of 100%, 50%, 25%, and 10%, in pot culture to assess their impact on wilt disease incidence.

Yasmin *et al.* (2016) carried out an experiment at the Horticulture Research Centre (HRC) of the Bangladesh Agricultural Research Institute (BARI) in Joydebpur, Gazipur from 2009 to 2011, employing an RCB design with four replications. Eight soil amendments, including poultry refuse (5 t ha-1), mustard oil cake (600 kg ha-1), Sesbania rostrata (5 t ha-1), municipal waste compost (5 t ha-1), BARI Trico-compost (2 t ha-1), and leachate (200 ml m-2), were assessed for their effectiveness against Fusarium wilt of gladiolus caused by *Fusarium oxysporum* f.sp. *gladioli*.

Singh (2021) evaluated six soil amendments: Neem cake, mustard cake, castor cake, Mahua cake, linseed cake, and FYM at a rate of 20.0 tons/ha. In the 2018-19 season, the highest disease incidence (30.12%) and yield (3.10 q/ha) were recorded on October 10, while the lowest disease incidence (10.00%) and yield (10.75 q/ha) were observed on October 30.

Singh *et al.* (2022) conducted an experiment during the Rabi seasons of 2018-19 and 2019-20 in the wire house of the Department of Plant Pathology at T.D.P.G. College, Jaunpur. This study, performed under pot culture conditions in both years, recorded PDC and yield-related characteristics. Among the six soil amendments used—Neem cake, mustard cake, linseed cake, Sesamum cake, castor cake, and vermi compost—neem cake was identified as the most effective for controlling wilt disease and promoting growth and yield in linseed. Conversely, vermi compost was the least effective soil amendment, yielding PDC values of 6.50 and 10.89 in 2018-19 and 2019-20, respectively.

IV. CHEMICAL CONTROL

Mukhopadhyay (1995) indicated that treating seeds is regarded as a method to significantly enhance their value and to foster plant growth and yield.

Dabkevicius and Gruzdeviene (2003) investigated the effectiveness of fungicides against seed-borne pathogens and plant diseases, as well as their impact on straw and linseed yields. The following seed treatments were applied 3-5 days before planting: Vitavax 200 FF (carboxin + thiram), Raxil (tebuconazole), Maxim Star (fludioxonil + cyproconazole), Fundazol (benomyl), Sportak (prochloraz), Rovral (iprodione), and Premis (triticonazole). Additionally, Folikur (tebuconazole + triadimefon) and Sportak (prochloraz) were sprayed during both the seedling and fir-tree stages of flax. Prior to treatment, 39-79% of the seeds were found to be affected by pathogens, with 26-51% showing infection from anthracnose (Colletotrichum lini) and Fusarium spp. Maxim Star and Sportak demonstrated the highest effectiveness against seed pathogens across all three years, with only 1.0-2.2% of seeds showing infection. Seed treatments led to increased straw and linseed yields in all years. Treatments with Maxim Star and Sportak raised straw yields by 11.0% and 6.2%, respectively. Applications of Vitavax, Fundazol, and Premis enhanced straw yields by 5.8-7.0% annually. Only Raxil and Rovral did not influence straw yield. Maxim Star contributed to a 22.1% increase in linseed yield, while Sportak and Premis resulted in increases of 13.7% and 13.3%, respectively. The findings suggest that seed treatment is more beneficial than fungicidal spraying for flax crops.

Maheshwari *et al.* (1981) observed that Carbendazim was the most effective fungicide for controlling fungal growth of *Fusarium oxysporum* f. sp. *lentis* (5.6 mm), followed by Captan (9.9 mm) and Hexaconazole and Diniconazole. The combination of seed treatment and soil drenching with Carbendazim was particularly effective in reducing wilt incidence (10.6%) and plant mortality (4.5%), yielding the highest grain output (7.48 q/ha). Hexaconazole showed the next best results in terms of disease incidence, plant mortality, and grain yield.

Singh *et al.* (2010) assessed six fungicides both in vitro and in vivo against *Fusarium oxysporum* f. sp. *lentis*, demonstrating that Carbendazim and Carboxin completely inhibited test pathogen growth, while Thiram and Captafol inhibited 87.5% and 83.1% of mycelial growth, respectively. Seed treatments using these chemicals improved germination rates (90.0 and 89.0), as well as root length (10.1 cm and 10.0 cm) and shoot length (4.8 cm for both). Foliar sprays with these two fungicides provided the best outcomes in decreasing wilt incidence from 37.5% to 5.0%.

Rajkumari *et al.* (2015) found that fungicides, botanicals, and bio-control agents that showed effectiveness in vitro were evaluated further in the field across two consecutive seasons as seed treatments, both individually and in combinations, to mitigate wilt and root-rot issues in chickpeas. The combined treatments outperformed individual ones in terms of improved germination, reduced mortality, and increased yields. The most effective treatment involved seed treatment with Tebuconazole combined with T. harzianum, followed by Vitavax combined with T. harzianum and the combination of Tebuconazole with T. harzianum and Tebuconazole with Tetracycline.

Manasa (2017) examined six fungicides for their effectiveness in mitigating Fusarium wilt in a carnation population. The fungicides were applied to the soil using the drenching method. The Fusarium population was assessed before the fungicide application and every 15 days until the 45th day following application. Among the fungicides tested, the first treatment resulted in a population of 1.66 × 10^3 cfu per gram of soil and a wilt incidence of 9.33%, while the second treatment had a population of 2.66 × 10^3 cfu per gram of soil and a wilt incidence of 11.19%. Both were significantly effective in reducing the soil population of Fusarium and the incidence of wilt in controlled conditions.

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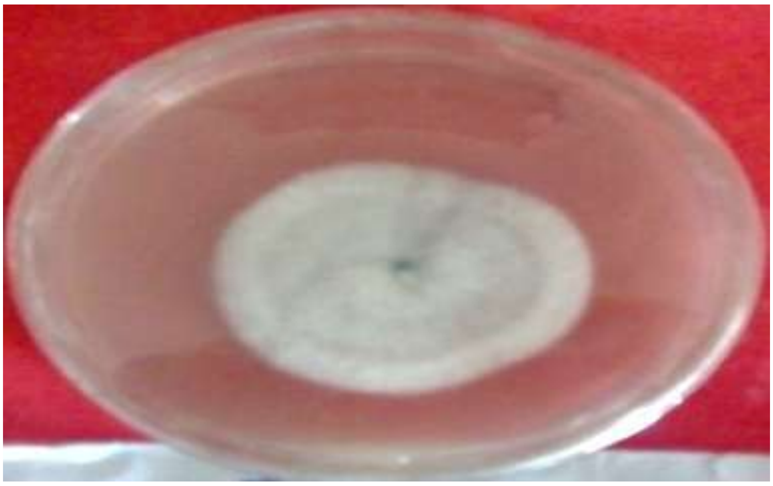
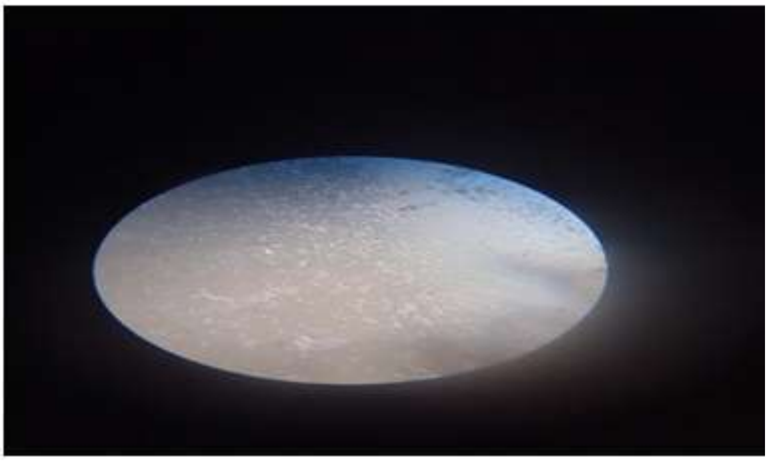
Field of linseed

Flowering stage of linseed crop



Culture of *Fusarium oxysporum* f.sp. *lini*

Microconidia of *Fusarium oxysporum* f. sp. *lini*



Macroconidia of *Fusarium oxysporum* f.sp. *lini*

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PHYSIOLOGICAL ADMINISTRATION AND HEALTH MONITORING: ROLE OF TRANSIENT IMPLANTABLE BIO-PIEZOELECTRIC MATERIALS

Abstract

Piezoelectricity is a ubiquitous phenomenon in biological systems. Recent breakthroughs in developing piezoelectric materials from biomass hold great promise for revolutionizing the fabrication of implantable biomedical devices, addressing key areas of medical research. The development of sophisticated physiological administration and monitoring devices has become a vital technique, enabling transient functionality without the need for future surgical operations after medical healing. Bio-compatible piezoelectric materials are particularly promising in device design, as they can harness indigenous electrical energy from mechanical stress, required for drug administration and monitoring. Recent technological innovations have created viable opportunities for the implantation of bio-microelectronic devices, enhancing the quality and span of life. Moreover, machine learning is providing valuable insights into complex biological processes and their interactions with various treatments and diseases, ultimately improving the medical treatments and quality of life. Humans possess various sources of energy, including mechanical, chemical, and thermal energy. These ambient energies can be converted into electrical energy, enabling the operation of autonomous,

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long-lasting implantable electronic devices.

Keywords: Piezoelectricity, Bioelectronics, Physiological Administration, Health Monitoring

I. INTRODUCTION

Certain crystalline materials with non-centrosymmetric crystal structures, lacking a center of symmetry, exhibit the appearance of equal and opposite charges on their opposite faces. This pressure-induced electrical response in material is known as piezoelectricity. Additionally, applying a voltage difference across the opposite faces of a piezoelectric crystal induces a shape change. Under stressed conditions, the crystal's center of charge gravity is disrupted due to the displacement of opposite charges in opposite directions. Which relies on producing an uncompensated electrical dipole. In the absence of a stress field, the symmetry of the crystal structure prevents the formation of a net electric dipole moment per unit cell, as shown in figure 1 (a) and (b). Due to their fascinating physical characteristics, piezoelectric crystals are promising in sensing and actuation technology and ambient energy harvesting from house hold application to artificial intelligence and machine learning. Piezoelectrics are used in gramophone pick-ups, accelerometers, ultrasonic transducers/receivers, and microphone devices for converting pressure into electrical signals. Quartz crystals are used in watches, computers, and phones to provide accurate timing.

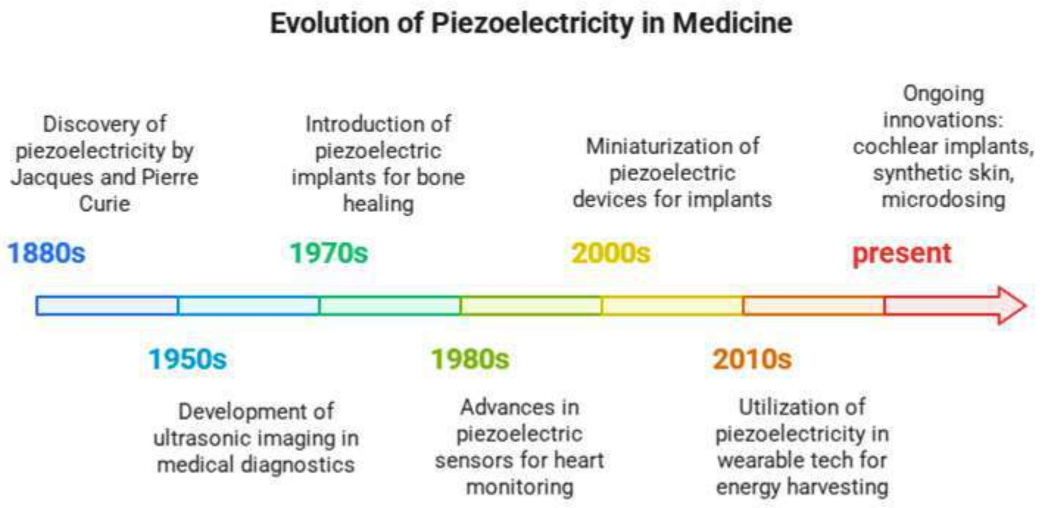

Figure 1: Advancement in piezoelectric technology for medical applications.

Furthermore, biological materials, including bone, proteins, and DNA, also exhibit similar electromechanical responses under stressed physiological environment[1]. Device implantation in the human body has been effectively devised as a tool for physiological administration and health monitoring, with applications in cardiac pacemakers, cochlear implants, cardioverter-defibrillators, artificial retinas, and stimulators for the nervous system, brain, and bone, serving as an adjunct in patient treatment.

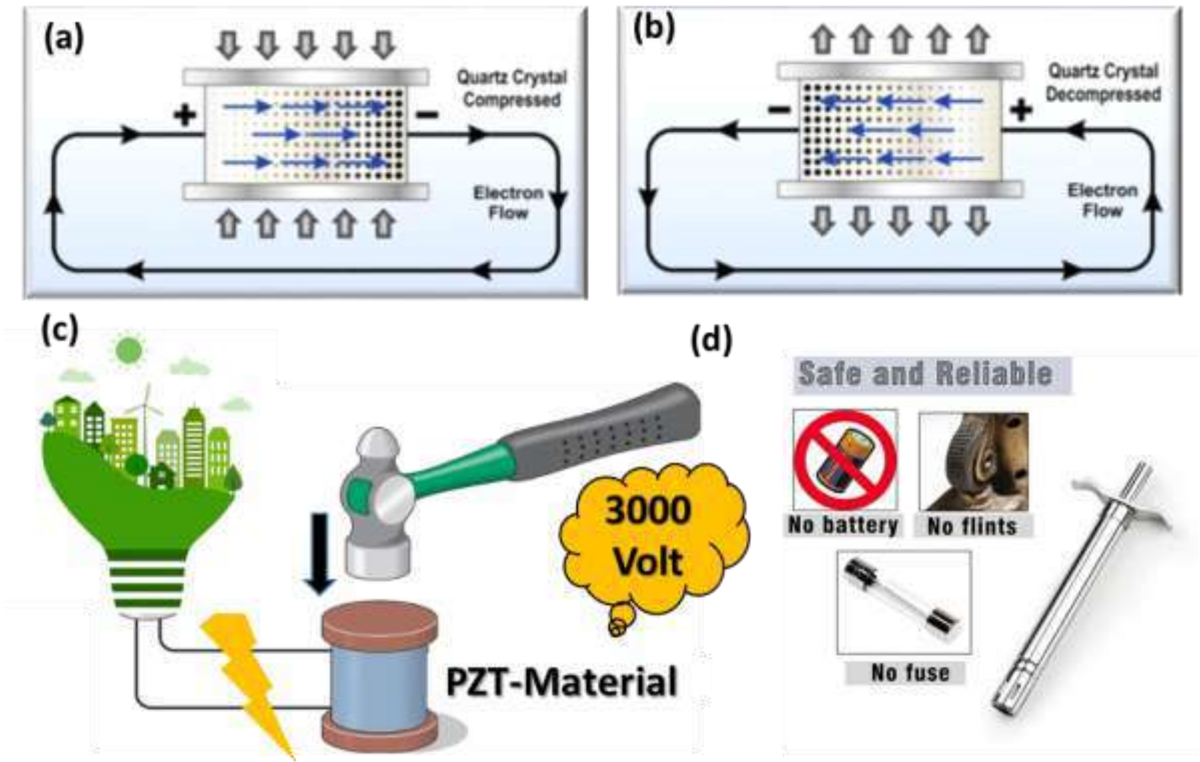

Figure 2: Schematic diagram of piezoelectric signal generation against mechanical pressure (a) application and (b) removal. (c) Potential use of waste mechanical energy harvesting (force, pressure, strain, vibration, etc.) in to electricity. (d) Domestic use of piezoelectric material as LPG gas lighter with the generation several kilovolt to generate spark. The launch of the first practical application for piezoelectric devices, the sonar device, coincided with the outbreak of World War I.

Non-biodegradable piezoelectric materials are already playing a vital role in medical diagnosis and imaging. However, $PbTiO_3$ and Pb-based materials are leading piezoelectric materials due to their outstanding electromechanical response. Nevertheless, the toxicity of Pb and environmental concerns have prompted the scientific community to develop competent Pb-free piezoelectric materials as alternatives to Pb(Zr,Ti)O_3. Furthermore, perovskite piezoelectric materials often exhibit unfavorable properties, such as being too hard, brittle, and non-biodegradable. They may also contain hazardous components due to decomposition or fluoride release. Consequently, these materials are considered unsuitable and incompatible for medical applications. For physiological applications, particularly tissue engineering, the interface material must exhibit flexibility, biocompatibility, and biodegradability. In living organisms, bioelectricity plays a significant physiological role – e.g., shin bone in human body produces a 300 μV signal when walking. Physiological signals are generally of low amplitude, quasi-periodic, and non-electrical, making them challenging to detect and perceive otherwise[2].

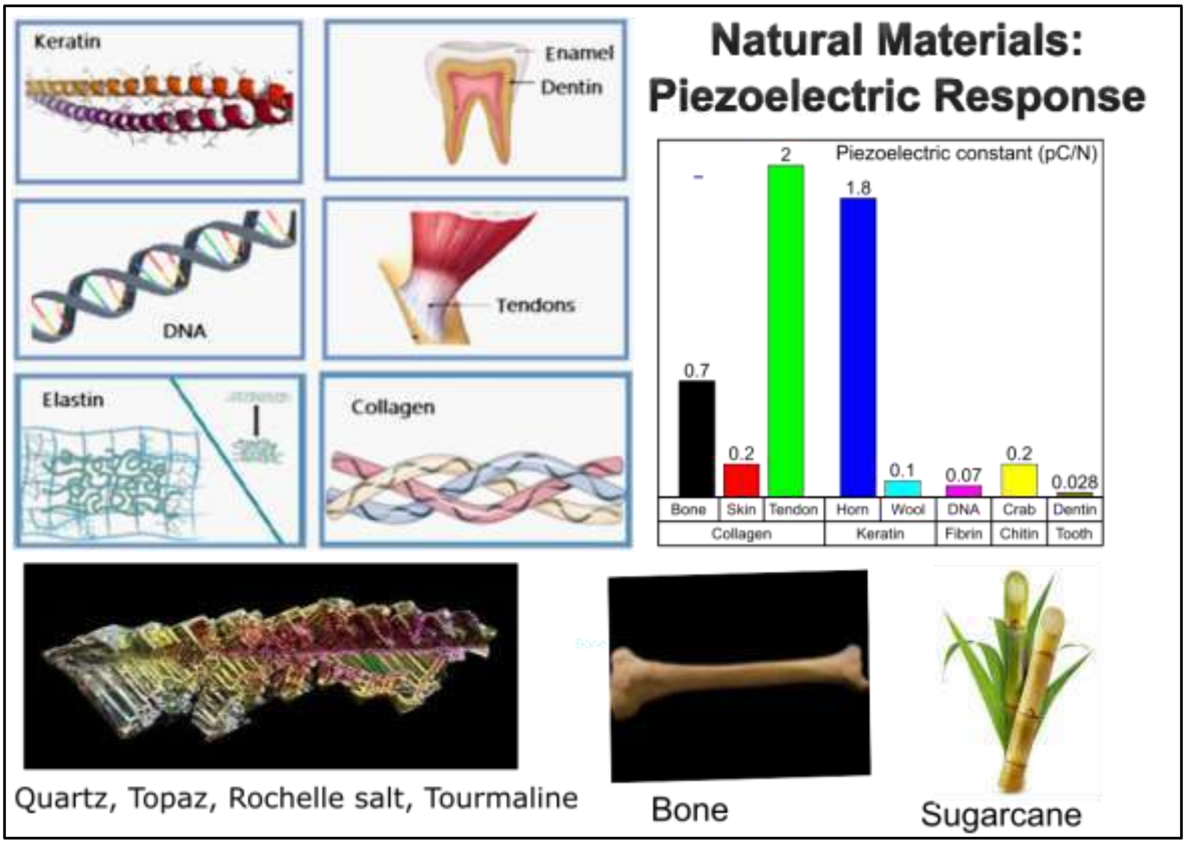

Figure 3: *Natural Piezoelectric Materials and their electromechanical response*[3]

II. PIEZOELECTRICITY IN LIVING SYSTEM

To meet sophisticated physiological requirements, conventional inorganic piezoelectric oxides pose significant challenges. In this regard, polymer-based piezoelectrics appear to be a suitable option for human body applications[4].

However, polymers with inferior piezoelectric properties require significant improvement in their electromechanical response to increase their therapeutic productivity in physiological systems. In principle, biodegradable piezoelectrics composed of amino acids, peptides, proteins, viruses, polysaccharides, collagen, and chitin have been found suitable for implantation due to their immune character, which resists infection and inflammation agents, as shown in figure 2, along with their piezoelectric response[5].

- **Amino Acids:** Amino acids typically possess a molecular structure comprising an amino group ($-NH_2$), a carboxyl group ($-COOH$), and a distinctive side chain (R). When subjected to mechanical stress, the alignment of dipole moments between the carboxyl and amino groups induces piezoelectric properties in amino acid crystals. Studies have revealed a wide range of piezoelectric coefficients among amino acids, varying from 0.5 pC/N to 178 pC/N. Specifically, the γ-glycine crystal exhibits a notable longitudinal charge coefficient (d33) of 10.4 pC/N, comparable to those of quartz crystals and zinc oxide.

- **Peptides:** Peptides, a short chains of amino acids, possess variety of structural, configuration, and physical characteristics – based on their constituent amino acids. As a result, the structurally ordered peptides molecules shows piezoelectric properties, similar to the amino acids. Notable examples of piezoelectric peptides include diphenylalanine, cyclo-glycine-tryptophan, fluorenylmethyloxycarbonyl diphenylalanine, cyclo-phenylalanine-tryptophan, and bis-cyclic-β-peptide. The origin of piezoelectricity in peptides is attributed to the electrical dipoles formed between carboxyl groups – amino group analogous to amino acids. However, the larger molecular size and additional functional groups present in peptides causes a complex inter-molecular interactions, distinguishing their self-assembly phenomena and piezoelectric performance from those of amino acids.

- **Protein:** Proteins are complex biomolecules comprising multiple amino acids, and play a essential physiognomies in retaining the body's structure, function, and regulation. Their biological activities are determined by their unique three-dimensional structure and amino acid sequence. Notably, piezoelectric properties have been identified in various proteins, including elastin, collagen, lysozyme and silk. However, the intricate chemistry and structural diversity of these proteins result in significant variations in their piezoelectric mechanisms and properties.

- **Collagen:** Collagen is one of the most abundant structural protein in the living species, accounting for approximately 1/3 of natural proteins. It is ubiquitous in various tissues, including tendon, bone, and muscle skin. The collagen-based products have received widespread approval from the United State Food and Drug Administration for commercial application as well as clinical uses. The hierarchical microstructure of collagens is characterized by a repeating 3-amino acid motif, G-X-Y, where G, X and Y are glycine, proline and hydroxyproline, respectively. This motif forms the foundation of triple helical/twisted polypeptide chains – which are stabilized by interstrand hydrogen bonds. The piezoelectric properties of collagen are attributed to the generation of electric dipoles through the peptide chain and hydrogen bonding.

- **Silk:** Silk is an attractive bio-piezoelectric-material, boasting exceptional bio-medical compatibility, desirable biodegradability, and remarkable flexibility. As early as 1956, Fukada discovered the piezoelectricity in silk fiber bundles, with a measured piezoelectric response of approximately 1 pC/N. However, this relatively low piezoelectric property is likely attributed to the poor crystallinity present in silk. Recently, driven by the increasing interest in flexible functional bio-inspired-materials, researchers have revisited silk's piezoelectric properties, sparking renewed attention in this area.

- **Lysozyme:** Lysozyme is globular protein that are abundant in mammalian secretions and egg whites, exhibits distinct properties that set it apart from fibrous proteins. A study by Stapleton et al. revealed that lysozyme films possess piezoelectric, ferroelectric, and pyroelectric properties. The researchers measured the piezoelectric-coefficients lysozyme films with monoclinic and tetragonal to be 0.94 pm/V and 3.16 pm/V, respectively.

- **Virus:** A virus is a microscopic infectious living agent comprising a nucleic-acid core surrounded by a protein-coat. The unique structural asymmetry of the capsid protein enables certain viruses to exhibit piezoelectric properties. Researchers at the Lawrence Berkeley National Laboratory (Berkeley Lab) have successfully engineered a harmless virus to function as a piezoelectric generator. By genetically modifying the virus, scientists created a novel material that converts mechanical stress into electrical energy. This innovative virus-based material holds promise for integration into wearable energy-harvesting devices, such as shoeembedded generators, which could potentially power portable electronics like smartphones.

- **Polysaccharides**: Polysaccharides, the most abundant and highly interesting natural carbohydrates in the biological framework, comprise monosaccharides with a general chemical formula of $C_x(H_2O)_y$. Which are ubiquitous in plants, animals and food, serving as structural and storage components[4]. As the most extensively studied piezoelectric biomaterials, polysaccharides have been the subject of numerous reviews, particularly paying attention on the piezoelectric properties of cellulose based nanocrystals.

III. SYNTHESIS

This section provides a brief insights into few fabrication methods for biodegradable piezoelectric materials. Biodegradable polymers are synthesized via microbial degradation or hydrolysis.

Polymerization routes: Polylactic acid, polyglycolic acid, polycaprolactone are synthesized via ring opening polymerization. Polyhydroxyalkanoates are synthesized via condensation polymerization. Chemical routes ring opening pol is a common method used to produce biodegradable polymers. Enzymatic synthesis is a method of synthesizing biopolymers using enzymes as catalysts. Microbial fermentation is a method of producing biopolymers using microorganisms such as fungi, bacteria, and yeast. In tissue engineering, 3D printing can be used to create scaffolds that mimic the structure and function of natural tissues.

To date, particularly biodegradable piezoelectric polymers, have been fabricated using various methods; including electrospinning, solvent casting, heat processing, and directional growth. This upgrade enhances both mechanical and biodegradable properties, ensuring they meet stringent quality standards while enabling scalable and cost-effective production.

IV. TRANSIENT IMPLANTABLE BIOELECTRONICS

Transient implantable medical devices offer a groundbreaking solution to overcome the complexities associated with traditional non-resorbable healthcare technologies. By harnessing the potential of these innovative devices, various shortcomings and unpleasant scenarios, such as long-term infection risks, inflammatory responses, and periodic medical interventions, can be effectively mitigated, ultimately enhancing patient comfort and quality of life. The elimination of surgical extraction needs has not only significantly improved comfort levels for patients and medical practitioners but also enabled bioelectronics to perform sophisticated functions, including sensing, stimulation, and real-time wireless data acquisition and analysis. These devices provide targeted treatment or monitoring for specific periods before safely degrading into non-toxic and harmless byproducts, dissolving in the body after completing their intended function[6].

V. PHYSIOGNOMIES OF BIOELECTRONIC DEVICES

Implantable devices must be compact and lightweight to minimize any unwanted impact on human activities. These devices are equipped with electrochemical batteries as a reliable power source. However, after a certain period, the battery becomes depleted and requires replacement. The limited lifetime of batteries (~5 years) also imposes an unnecessary burden. To achieve uninterrupted functioning, the devices must be energy-autonomous, harnessing power from physiological activities, such as thermal energy, mechanical energy, and chemical sources in vivo. In this regard, piezoelectric materials can convert muscle motion and organ vibrations into electrical energy, empowering device operation without interruption. Piezoelectric sensors offer inherent benefits, including versatility, robustness, affordability, simple architecture, good thermal and frequency stability, steady electromagnetic radiation response, and desirable elasticity, making them suitable for energy harvesting from in vivo vibrations. Energy harvesting systems for physiological use must be extremely slim, flexible, and lightweight. Polyimide, polyethylene naphthalate, and polyethylene terephthalate are commonly used as substrates in device fabrication. Recent advances in piezoelectric materials and piezoelectric-based energy generators have shown great promise in addressing existing issues. These innovations can be widely employed in energy generators and nanosensors (capable of detecting nanoscale deformations in biological cells) for various biomedical applications[7].

VI. CLINICAL MONITORING

Early detection of vital signs driven by disease and its real time monitoring unveils a pathway on prevention of disease and complications[8]. Key vital signs, including electrocardiogram (ECG) readings, heart rate, respiratory rate, blood pressure, and pulse pressure, provide invaluable insights into an individual's

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overall wellbeing status. The real time data acquisition on these physiological response and its accurate analysis has become important in today's technology. Which allows medical practitioners to monitor the health progress and helps to take necessary action immediately. In this regard, the device implantation may provide realistic solution towards speedy measurement and proper signal interface between patient and spectrum analyzer. Indeed, piezoelectric-based probing techniques are revolutionizing diagnosis by offering real-time monitoring capabilities at a low cost and with widespread availability. ECG monitoring can be readily available at reasonable rates with the implement of piezoelectric sensor[9]. Bone tissue inherently possesses piezoelectric properties. The endogenous electric signals in bone can inspire innovative therapeutic approaches that enable bone to adeptly renovate itself in response to treatment. The use of Bluetooth enabled bioelectronics holds promise for effectively enhancing bone regeneration and physiological processes[10]. Piezoelectric sensors have been employed to non-invasively monitor human vital signs, specifically heart rate and respiratory activity, via measurements taken from the chest surface – with conformal mapping of the cardiorespiratory activities[11]. The oxygen level in hemoglobin can be managed with the generation of surface charge in respiration system with the use of piezoelectric materials. β-Nanocellulose has been studied as a potentially novel orthotropic 2D piezoelectric crystal[12]. Such developments provide a rationale for modeling the extended piezoelectric effect and inform the design of new artificial piezoelectric materials. Thus, bio-inspired piezoelectric materials that replicate the natural processes found in biological systems hold great promise for biomedical applications, particularly in the areas of tissue repair and regeneration.

VII. PHYSIOLOGICAL ADMINISTRATION

Electrical therapies for heart conditions are limited by the need for invasive electrode implantation and the heart's complex anatomy. To address this challenge, X. Zhao et al.[13] developed a wireless electrical stimulation system that controls poly-L-lactic acid piezoelectric nanofibers to enhance bioelectric propagation and cardiac electrical activity. This breakthrough offers a promising new direction for treating heart diseases and potentially enables wireless cardiac pacing applications[13]. Q. Lv et al.[14] developed a silk sericin protein film-based, implantable, battery-free piezoelectric energy generator to power next-generation cardiovascular electronic devices. D. Wang et al.[15] implanted a nanogenerator on the surface of a pig's heart. This integrated power system successfully charged a 100 μF capacitor to 4 V in just 13 minutes, generating sufficient electrical power to operate a commercial pacemaker and provide regular stimulation signals. Z. Lin et al.[16] proposed an electrical stimulation (ES) therapy for exercise-driven cartilage regeneration, utilizing hierarchically structured piezoelectric scaffolds composed of polyvinylidene fluoride/zinc oxide/polycaprolactone (PZP). These scaffolds were fabricated using a combination of 3D printing and rolling techniques, demonstrating potential for promoting cartilage regeneration as a treatment for osteoarthritis. Curry et al.[17] fabricated a force sensor to detect bio-physiological pressures/forces with controlled biodegradability and piezoelectricity. T. Vinikoor[18], demonstrated physiological response of poly-L-lactic acid nanofibers embedded inside a collagen matrix. Which suggests that the piezoelectric hydrogel with ultrasound can enhance cell migration and induce stem cells to secrete TGF-β1 (transforming growth factor). Which increased subchondral bone formation, improved hyaline-cartilage structure, and good mechanical properties, close to healthy native cartilage. M. T. Chorsi et al.[19] has shown state-of-art biodegradable transducers and employed for facilitating the delivery of chemotherapeutic drug to the brain. Y. Shan et al.[20], employed an implantable PLLA/BTO piezoelectric sensor for real time monitoring of recovery after nerve injury is developed. Y. Liu et al.[21], have discovered that poly(l-lactic acid) (PLLA) nano-fiber framework under stress or joint load act as a battery-less electrical stimulator to promote chondrogenesis and cartilage regeneration. H. Xue et al.[22] emphasized the potential of self-aligned piezoelectric γ-glycine/polyvinyl alcohol (γ-glycine/PVA) films, fabricated via an ultrasound-assisted process. These γ-glycine/PVA biofilms exhibit strong piezoelectricity. Furthermore, the biofilms were developed into wireless piezo-ultrasound electrotherapy devices, demonstrating accelerated wound healing with a ~40% reduction in healing time and self-degradation in preclinical wound models. Y. Fan et al.[23] provided indigenous route for the treatment of tumors using a combined effect of catalysis and immunotherapy. In this novel treatment, microrobot was designed using Veillonella atypica (VA) cells loaded with Staphylococcus aureus cell membrane-coated BaTiO3 nanocubes (SAM@BTO). This microrobot disrupts the immunosuppressive microenvironment by oxidizing lactic acid, promoting dendritic cell maturation, macrophage polarization, and T cell activation. Wu et al.[24] investigated the in vivo degradation behavior of PLA-encapsulated PHBV/PLLA/KNN nanogenerators through microtomography imaging over a 12-week period. Additionally, they examined the degradation of poly-ε-caprolactone (PCL) encapsulated PHBV/PLLA/KNN piezoelectric films in PBS for 32 weeks. Initially, the device maintained its structural integrity for 12 weeks with drop in output performance, decreased by 20% compared to the initial value. However, after 16 weeks, significant mass loss was observed, and the device completely degraded within the 32-week timeframe.

Breast Cancer Detection: Existing diagnostic tools, such as magnetic resonance imaging, tomography, mammography, ultrasound, and biopsy, are expensive and time-consuming[25]. There is an urgent need for probing techniques that offer rapid and high-sensitivity detection for early-stage cancer evolution. To address this, a piezoelectric sensor was developed to detect human epidermal growth factor receptor (HER2) biomarker levels in human blood samples from breast cancer patients[26]. The anti-HER2 piezoelectric biosensor accurately detected naturally occurring and recombinant HER2 at clinically relevant levels (>2 ng/mL). These findings affirm that the PEM biosensor is an effective tool for breast cancer exposure.

Bio-e-skin: A flexible and wearable piezoelectric bio-electronic skin (PBio-e-skin) based on an electrospun poly(L-lactic acid) nanofiber membrane has been demonstrated for non-invasive human physiological signal monitoring and dynamic tactile stimuli detection. The molecular orientations of the C=O dipoles, achieved through the electrospinning technique, result in a longitudinal piezoelectric charge coefficient (d33) value of 3 pmV^{-1}. This enables the PBio-e-skin for pressure sensing applications. Sultana et al. successfully monitored human physiological signals, tracked sports performance, and recognized voice patterns[27].

Tissue Engineering: Novel electrospinning method for fabricating poly(l-lactic acid) nanofibers (PLF) with enhanced cytocompatibility, surface properties, and piezoelectricity, leveraging carbon nanomaterial (CM) and polydopamine (PD) coating strategies. PLF scaffolds with tunable surface and piezoelectric properties to create a favorable extracellular microenvironment, promoting tissue regeneration and accelerating the healing process. Kim et al. developed BTNP-pDA-BNN6, comprising N, N′-di-sec-butyl-N, N′-dinitroso-1, 4-phenylenediamine (BNN6) and BT nanoparticles coated with polydopamine (pDA). These nanoparticles were designed to alleviate Parkinson's disease (PD) diagnosis using localized electrical stimulation under ultrasound excitation. This groundbreaking research underscores the vast potential of ultrasound in wireless piezoelectric stimulation for neural tissue engineering[28].

Bone Regeneration: In a subcutaneous implantation demonstrated higher proportion of macrophages in tissues surrounding poled BT/Ti scaffolds subjected to low-intensity electrical stimulation. Notably, this phenomenon was accompanied by enhanced macrophage M2 polarization and bone regeneration[29].

Electrical Stimulation: Mechanical stimulation of the poly-L-lactic acid/reduced graphene/polydopamine fibrous scaffold promoted cell growth and matrix production. Furthermore, prolonged degradation of the scaffold over 21 days enhanced glycosaminoglycans synthesis in ATDC5 cells, outperforming the 7-day degradation period[30]. A fully integrated implant (mass: 78 mg) was successfully operated at a depth of 10.5 centimeter in a tissue phantom, powered by ultrasound. The implant achieved a compliance voltage of 15 V, suitable for chronic applications. The successful integration of implant components, comprehensive in vitro system characterization, and effective electrical stimulation of the sciatic nerve demonstrate the feasibility and efficacy of the proposed peripheral nerve stimulator[31].

Powering to Transient Medical Implant: However, the development of associated biodegradable power sources remains a significant challenge for future clinical applications, as the demonstrated electrical stimulation and sensing functions are currently limited by reliance on wired external power or wireless energy harvesting via near-field coupling[32]. Transient implants require innovative powering solutions to enable reliable, efficient, and sustainable operation. According to S. Sevlarajan et al., the power density of a 0-3 composite film composed of nanoparticles of $BaTiO_3$ and poly(L-lactic-co-glycolic) acid polymer can reach up to 10 mW/cm^2 when powered ultrasonically, with complete biodegradation in physiological conditions within 100 days[33].

Future Outlook: Nevertheless, biomaterials exhibit a relatively weak piezoelectric response compared to ceramics and polymers. Furthermore, achieving domain alignment in piezoelectric biomaterials remains a significant challenge. These challenges can be addressed through molecular design, complex heterostructures, and optimization of polarization orientation and direction. The global implantable medical device market has witnessed rapid expansion in recent years. According to Zion Market Research, the global Bio-Piezoceramics Market was worth USD 19.73 Billion in 2023. The market is forecast to reach USD 34.20 billion by 2032, found to be growing at a compound-annual-growth-rate (CAGR) of 6.3% during the forecast period 2024-2032[34]. Market of bioelectronics device based Market size was at USD 31.78 billion in 2023 and is expected to grow to USD 70.8 billion by 2032 and grow at a CAGR Of 9.32 % over the forecast period of 2024-2032[35].

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SPINTRONICS: A QUEST FOR HEALTH AND ENVIRONMENT

Abstract

Spintronics, or simply spin mediated electronics is the study of active control and manipulation of spin degrees of freedom in solid-state systems. This chapter emphasizes the current status of this subject and future perspective in respect to the challenges in environmental and healthcare sectors. This chapter highlights both recent advances and well-established results in this field. The primary focus is on the understanding of basic physical principles underlying the generation of carrier spin and its polarization. The spin dynamics and the spin-polarized transport in semiconductors and metals has been discussed. Spin transport is very different from charge transport, the most intriguing fact is that spin is a non-conserved quantity in solids due to spin-orbit and hyperfine coupling. The authors have discussed in detail spin mechanisms and their possible use in healthcare and energy harvesting. Spintronic devices can play an important role in high performance low energy technology, thereby it can help environmentally. It is however in a nascent stage now but has great potential for future generation researchers. There are various theories of spin injection and spin-polarized transport, that are applied to hybrid structures relevant to spin-based devices and fundamental studies of materials properties. Experimental works are reviewed with the emphasis on projected

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applications. In some cases, the external electric and magnetic fields and illumination by light can be used to control spin and charge dynamics to create new functionalities which are not feasible or ineffective with conventional electronics. In this book chapter, we will provide a brief introduction to various aspects of spintronic materials, a novel phenomenon associated with energy harvesting and their future roadmap in the renewal of ambient energy, technological prospects and healthcare.

Keywords: Spintronics, Memory storage, Healthcare, Environment sustainability

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I. INTRODUCTION

Spintronics, short for spin electronics, is a subfield of electronics that studies the intrinsic spin of electrons and its associated magnetic moment. Unlike traditional electronics, which primarily focuses on the charge of electrons, spintronics utilizes the spin properties of electrons to store, manipulate, and transmit information. Spintronics is a revolutionary field of electronics that taps into the intrinsic spin of electrons, harnessing their magnetic properties to store, manipulate, and transmit information. By leveraging the unique properties of electron spin, spintronics has the potential to surpass traditional electronics in terms of speed, efficiency, and storage capacity. A few applications of spintronics are magnetic storage devices (hard drives), magnetic sensors, Spin-based logic devices and quantum computing. The biggest advantages of spintronics are higher storage density, lower power consumption and faster data processing etc. while a lot has been talked about the technology, the main challenges in fulfilling the technological achievements are maintaining spin coherence, scaling up spintronic devices, and integrating spintronics with traditional electronics etc. Some key concepts behind the spintronics are discussed below.

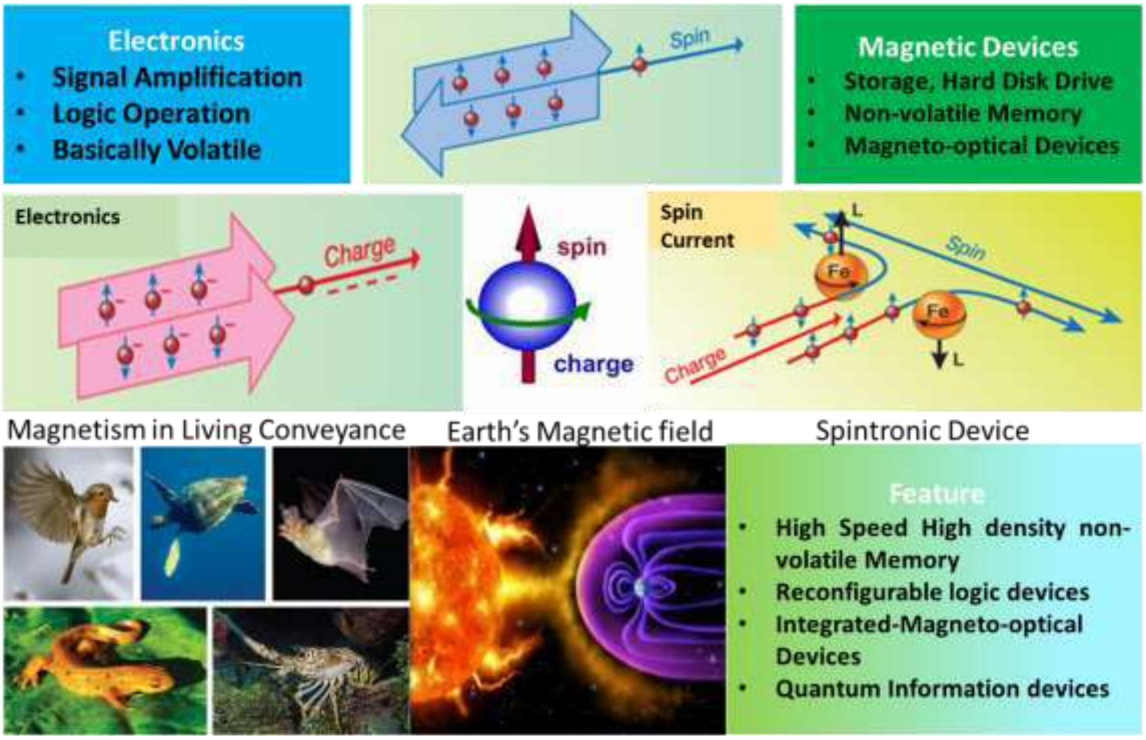

Figure 1: Basics of electronic and spin theory, schematics of spin+electronics as spintronics, living body with magnetic sensors, earth as source of ambient magnetic field, promising features of spintronic devices.

In spintronics, the spin of electrons plays a crucial role. The spin of an electron is a fundamental property that can be described using the spin angular momentum operator:

$$\vec{S} = (Sx, Sy, Sz) = \frac{1}{2}\hbar\vec{\sigma} \quad (1)$$

Where ħ is the reduced Planck constant, and $\vec{\sigma} = (\sigma_x, \sigma_y, \sigma_z)$ are the Pauli spin matrices:

$$\sigma_x = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \quad (2)$$

$$\sigma_y = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} \quad (3)$$

$$\sigma_z = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad (4)$$

The magnetic moment of an electron is related to its spin:

$$\vec{\mu} = -g\mu_B\vec{S} \quad (5)$$

Where g is the electron g-factor, μB is the Bohr magneton, and S is the spin angular momentum operator. The spin-orbit interaction is a crucial mechanism in spintronics, as it allows for the manipulation of electron spin:

$$H_{so} = \left(\frac{\hbar}{2m}\right) \left(\vec{E} \times \vec{p}\right) \cdot \vec{\sigma} \tag{6}$$

Where E is the electric field, p is the momentum operator, m is the electron mass, and σ is the Pauli spin matrices. Spin transfer torque (STT) is a phenomenon where a spin-polarized current can exert a torque on a magnetic moment:

$$\tau = (\hbar/2e)\left(\vec{J} \times \vec{M}\right) \tag{7}$$

Where τ is the STT, ħ is the reduced Planck constant, e is the elementary charge, J is the spin-polarized current density, and M is the magnetic moment. GMR is a phenomenon where the resistance of a magnetic multilayer structure changes in response to a magnetic field:

$$R = R_0 + \Delta R \cdot \cos\theta \tag{8}$$

Where R is the resistance, R0 is the baseline resistance, ΔR is the magnetoresistance, and θ is the angle between the magnetizations of the two magnetic layers. Spin injection and detection are crucial processes in spintronics:

$$\vec{J} = \left(\frac{\hbar}{2e}\right)(\vec{\mu} \times \vec{\sigma}) \tag{9}$$

where J is the spin-polarized current density, ħ is the reduced Planck constant, e is the elementary charge, μ is the chemical potential, and σ is the Pauli spin matrices. These equations form the foundation of spintronics, governing the behavior of electron spin and its interactions with magnetic fields and electric currents.

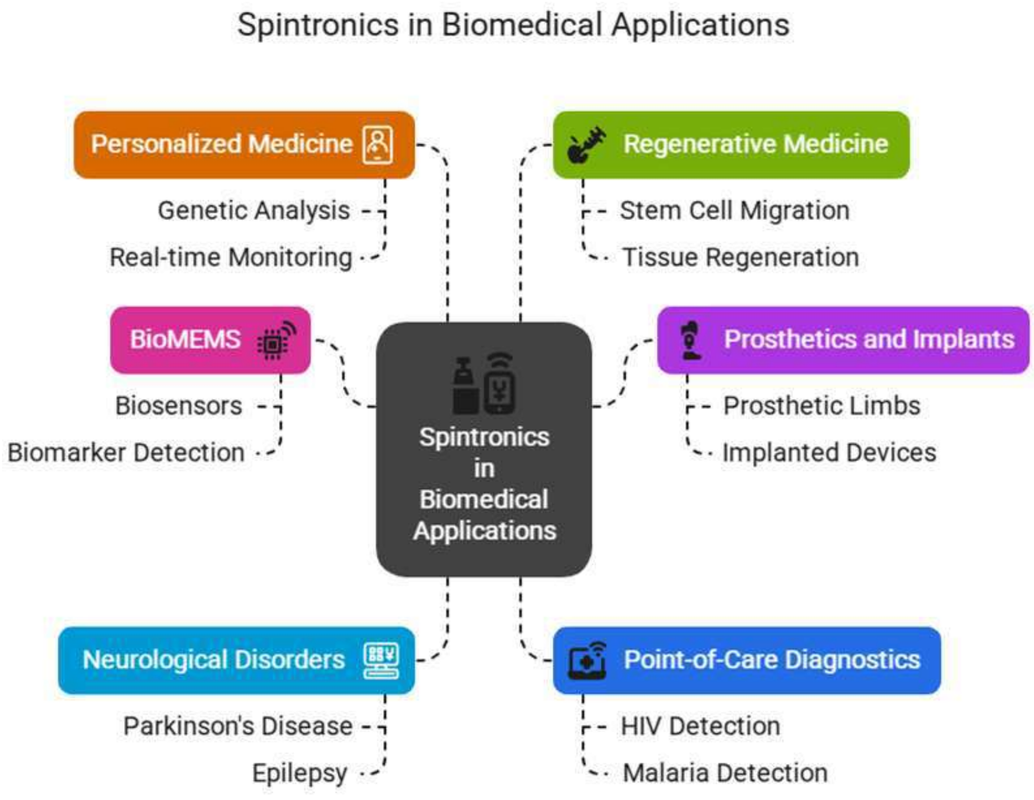

Figure 2: Future Biomedical Application of Spintronics.

Potential Application in Healthcare

- **Magnetic Resonance Imaging (MRI) Advancements:** Spintronics can improve MRI sensitivity and resolution, enabling earlier disease detection and more accurate diagnoses. Spintronics can improve MRI technology in several ways:
  - ➢ Spintronic sensors can detect weaker magnetic signals, enabling higher-resolution images and earlier disease detection.
  - ➢ Spintronic devices can speed up the imaging process, reducing scan times and making MRI more accessible.
  - ➢ Spintronics can enable MRI machines to operate at lower magnetic fields, reducing costs and making the technology more widely available.

- **Biocompatible Sensors:** Spintronic sensors can monitor biomagnetic fields, tracking neural activity, and cardiac function. This can help diagnose neurological and cardiac disorders. Spintronic sensors can be designed to be biocompatible, allowing for:

- Spintronic sensors can detect neural activity, enabling researchers to better understand brain function and develop new treatments for neurological disorders.
- Spintronic sensors can track cardiac function, helping diagnose cardiovascular diseases and monitor treatment efficacy.

- **Targeted Cancer Treatment:** Magnetic nanoparticles can be designed to target cancer cells, allowing for focused treatment and reduced side effects. Magnetic nanoparticles can be designed to target cancer cells, allowing for:
  - Magnetic nanoparticles can deliver chemotherapy or radiation directly to cancer cells, reducing side effects and improving treatment efficacy.
  - Magnetic nanoparticles can be designed to detect cancer biomarkers, enabling earlier diagnosis and treatment.

- **Neuroprosthetics and Brain-machine Interfaces:** Spintronic devices can enhance neural signal processing, potentially restoring motor function in paralyzed individuals or improving cognitive abilities. Spintronic devices can enhance neural signal processing, potentially:
  - Spintronic devices can help restore motor function in paralyzed individuals by decoding neural signals and controlling prosthetic limbs.
  - Spintronic devices can enhance cognitive function by decoding neural signals and providing real-time feedback.

- **Magnetic Bacteria Detection:** Spintronic sensors can rapidly detect magnetic bacteria, enabling swift identification of infections and early intervention. Spintronic sensors can rapidly detect magnetic bacteria, enabling:
  - Spintronic sensors can quickly identify magnetic bacteria, allowing for early intervention and treatment.
  - Spintronic sensors can be integrated into portable diagnostic devices, making healthcare more accessible and convenient.

- **Personalized Medicine:** Spintronic devices can analyze biomarkers, helping tailor treatment plans to individual patients' needs. Spintronic devices can analyze biomarkers, helping:
  - Spintronic devices can analyze biomarkers to identify the most effective treatment plan for individual patients.
  - Spintronic devices can track biomarkers to monitor treatment efficacy and adjust treatment plans accordingly.

- **Point-of-care Diagnostics:** Portable spintronic sensors can perform rapid, low-cost diagnostics, making healthcare more accessible and convenient. Portable spintronic sensors can perform rapid, low-cost diagnostics, making healthcare more:
  - **Accessible:** Spintronic sensors can be integrated into portable diagnostic devices, making healthcare more accessible in resource-limited areas.
  - **Convenient:** Spintronic sensors can provide rapid test results, reducing wait times and improving patient outcomes.

These applications demonstrate the vast potential of spintronics in transforming healthcare. However, it's essential to note that these technologies are still in the early stages of research and development.

Spintronic Technology: A Quest for Environmental Sustainability

- **Energy Efficiency:** Spintronic devices can operate at lower power consumption levels than traditional electronics. This is because spintronic devices rely on the manipulation of electron spin rather than charge, which can be a more energy-efficient process. Spintronic devices can perform data processing tasks at lower power consumption levels, reducing the energy footprint of data centers and mobile devices. Spintronic memory technologies, such as MRAM and STT-RAM, offer low-power data storage solutions, reducing the energy consumption of memory-intensive applications.

- **Low-Power Data Storage:** Spintronic memory technologies, such as MRAM and STT-RAM, offer low-power data storage solutions. These technologies rely on the manipulation of electron spin to store data, which can be a more energy-efficient process than traditional memory technologies. Spintronic memory technologies can reduce the energy consumption of memory-intensive applications, such as data centers and mobile devices. Spintronic memory technologies can offer higher data storage densities than traditional memory technologies, reducing the number of devices needed to store a given amount of data.

- **Reduced E-Waste:** Spintronic devices can be designed for greater durability and recyclability, minimizing electronic waste and the environmental harm caused by toxic materials. Spintronic devices can be designed with recyclability in mind, reducing the amount of waste generated during the manufacturing process. Biodegradable materials: Spintronic research aims to develop biodegradable materials that can easily decompose, reducing electronic waste and minimizing environmental harm.

- **Sustainable Materials:** Spintronic research explores the use of sustainable, eco-friendly materials, such as graphene and other 2D materials. These materials can replace traditional materials with higher environmental impact. Graphene and 2D materials: Graphene and other 2D materials are highly conductive, flexible, and sustainable, making them ideal for use in spintronic devices. Spintronic devices can be manufactured using recycled materials, reducing the demand for primary materials and minimizing waste.

- **Environmental Monitoring:** Spintronic sensors can be used for environmental monitoring, tracking pollutants, and detecting climate changes. These sensors can be designed to detect specific environmental pollutants, such as heavy metals or toxic chemicals. Spintronic sensors can be used to monitor air quality, detecting pollutants such as particulate matter, nitrogen dioxide, and ozone. Spintronic sensors can be used to monitor water quality, detecting pollutants such as heavy metals, pesticides, and industrial chemicals.

- **Water Quality Monitoring:** Spintronic sensors can be used to monitor water quality, detecting pollutants and contaminants that can affect human health.

While spintronic technology is still evolving, its potential to contribute to a more sustainable future is substantial. As research advances, we can expect to see more innovative, eco-friendly applications of spintronics emerge.

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OVERFISHING: A SERIOUS PROBLEM FOR INDIAN FISH BIODIVERSITY

Abstract

Fish is a cold-blooded aquatic organism that breathes with gills and swims with fins and live in water. India is second largest nation as fish producer with a significance part of its fish production coming from inland fisheries.

Overfishing is a serious problem to contribute depletion in fish diversity, density and distribution patterns in the biodiversity systems. Due to declining nature of fishing in the recent years as a result of several environmental factors, all age groups of fishes, small and large size fish catching by people in the competitive fishing operations which is major impact in future may cause serious decline in fish stocking. The changing land use practices, increasing population, agricultural expansion and pollution are major problems to the fish ecosystem. Particularly in the flood zone, encroachment in riparian area is one of the threats, and due to the loss of fish biodiversity along the river margin, soil erosion takes place and this result in loss of habitat sites in water system hasmajor impacted biodiversity. A socio-economic result of the fishermen entirely depends upon the fish biodiversity. A drastic Overfishing can produce major problem in loss of biodiversity, habitats and ecosystems that make vital contributions to the climate, environment, water and food. Due to overfishing it can include

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various economic fish species are endangered level such as some sharks, shardine, tuna, snapper and other fresh water fishes to challenging for Indian fish biodiversity.

Keyword: Overfishing, Biodiversity, Fish, Fresh water, ocean water.

I. INTRODUCTION

Fish culture is an important source of food, nutrition and employment for millions people to especially the rural populations. Fishes are an affordable and rich source of animal protein, is one of the healthiest options to mitigate hunger and nutrient deficiency (Mohanty, 2022).

It is important to consider the sustainability of the fishing industry in India, especially with the recently increase in fish catching activity and the introduction of more than 5,000 mechanized fishing methods (Pathak et al, 2022).

In India high demand for fish continues to increase with population growth as well as increases in consumption of animal protein associated with urbanisation and rising incomes. In developed countries, demand for high-value carnivorous fish species has also increased, mostly due to income growth and urbanisation, as well as a shift in preferences away from red meat and towards fisheries products (Delgado, Wada, Rosegrant, Meijer and Ahmed 2003).

Generally marine fish culture have very important roles for food supply, food security and income production in India. Approximately one million people work directly in this field. Due to overfishing, habitat destruction and fish production from marine fisheries is stagnant in recelally ten years back. Fish biodiversity changing is projected to exacerbate in this situation and act as a depensatory factor on fish populations. Hot of water has produce potential impact on fish diversity, distribution, abundance and diversity change, which effects on the ecosystem structure and function. Increased prevalence of extreme events such as storms, drought and floods are affect the safety and efficiency of fishing operations, flow of rivers and water availability and severe impacts on fisheries. The potential outcome for overfishing may be decrease in production and importance of fisheries in the economic returns from fishing operations.

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Fishes are high-protein source of omega-3 fatty acids, minerals, and other highly nutrients. The people of India consume fish on a daily basis. The price of fish and fish products grow on a daily basis due to rising of demand.

1. Types of Fresh Water Fishes in Indian Ecosystem

In India, the freshwater fishes are most important fish-culture production systems. Fresh water fisheries is the commercial cultivation and the rearing of fish in freshwater system like as tanks, ponds, lake and river for food production.

Table 1: Various types of fresh water fishes found in India

S.No.	Fish name	Common name	Uses	Refernecs
1.	*Labeo rohita*	Rohu	Food and Medicine	F.B. Hamilton
2.	*Catla catla*	Bhakur	Food and Medicine	F.B. Hamilton
3.	*Cirrhinus mrigala*	Nain	Food and Medicine	A. Hamilton
4.	*Anabas testudineus*	Anabas	Food and Medicine	Bloch
5.	*Wallago attu*	Parhin	Food and Medicine	Bloch & Schneider
6.	*Mystus seenghala*	Dariai Tengera	Food and Medicine	Sykes
7.	*Heteropneustes fossilis*	Singhi	Food and Medicine	Bloch
8.	*Clarias batrachus*	Mangur	Food and Medicine	Linnaeus
9.	*Channa gachua*	Sauri	Food and Medicine	F.B. Hamilton
10.	*Notopterus chitala*	Chital	Food and Medicine	F.B. Hamilton

2. Type of Fishes in Indian Ocean Ecosystem

Oceanic fishes that spend most or all life in seawater, such as Seas and Oceans, having salinity above 30 ppt. There are approximately 240 fish species are contributing to the marine fisheries. Example: Sardines, Tuna, Mackerel, Snapper, Pomfret etc. Diversity of organisms within the natural environment is important. The biodiversity decreasing level of deep sea fishes in the marine ecosystem is due to anthropogenic activities and overexploitation of marine resources (Alina et al., 2012). Aesthetic nature of marine ecosystem was reduced drastically by involving much anthropogenic activities in coastal area. Variety of various marine fishes collection must be graded, consumable and non consumable fishes. In this a findings that envisage the diversity of non-edible fishes in the specified catching region. Overfishing is major problem to dreadful consequences that affect biodiversity in the oceans as well as the social and economic value of Humans who mostly depend on fish for their way of life (Rinkesh, 2020). Today, 19.2 Kg of fish is consumed per each person every year, around twice as much as 50 years ago (FAO, 2014). Thus, in 2018, around 6 billion tons of fish and other invertebrates were caught from the seas worldwide, which means 30 to 35% of the marine population were overfished with 60% fully fished based on the latest available data. (FAO, 2018). Many seas and oceans around the world are subject to unsustainable fishing practices including 40% of fish stocks in the North-East Atlantic and 87% in the Mediterranean and Black Seas (STECF, 2019).

Table 2: Types of edible Oceanic fishes found in India

S.No.	Fish name	Distribution	Uses	Refernecs
1.	Tuna	coastal cuisine	Food, Flavour	Esme Raji
2.	Snapper	Subtropical Region	Food	Felipe Poey
3.	Trevally	Pacific Ocean	Food,Oily meat	Peter Forsskal
4.	Barracuda	Andhra Pradesh, Kerala	Food	Klein
5.	Pomfret	Gujrat, Orissa	Food	Dr.C.M. James
6.	Mackerel	Kolkata	Food	Linnaeus
7.	Sardine	Keral, Tamil Nadu	Food, Medicinal	Trevor Day

3. Impact of Overfishing on Derived Biodiversity Loss of Indian Fishes

The ocean comprises 99.8% of the habitable volume of our planet, yet its resources are not inexhaustible (*Dawson, 2012*). Around the world, the intensity, spatial reach, and technical capacity of fisheries have expanded enormously over the past half-century (Amoroso et al, 2018). As a consequence, overfishing is unquestionably the primary threat to ocean biodiversity (McClenachan et al 2016). many exploited species of fishes go unmonitored, making it difficult to track the extinction of marine fish species (Cashion et al, 2019). The statistical approaches used to extinctions are typically based on time series of sightings data, which are difficult to obtain for wide-ranging species, particularly marine fishes (Boakes et al 2015). As a consequence, marine extinctions have been overlooked, as many marine populations have been exploited to the point of collapse long before monitoring began (Webb et al 2015).

Based on the information available, it appears that overfishing is a significant issue in India, with a large number of fish stocks being overfished or in danger of overfishing for loss of biodiversity. Common marine species caught include Indian oil sardine, mackerel, Snapper, black pomfret, catfishes, and tunas. According to the CMFRI, 36.3% of fish stocks in India are overfished, 26.5% are currently in the process of recovering, and 3.1% are currently experiencing overfishing (Sasikumar et al, 2023). However, there are some positive signs, such as the fact that 34.1% of assessed fish stocks in India are sustainable, and some states, such as Goa, West Bengal and Kerala, have a high percentage of sustainable fish stocks (Sathianandan et al, 2021). According to the Central Marine Fisheries Research Institute's (CMFRI) reports, the quantity of fish caught has risen by approximately 38%, from 1.23 lakh tonnes in 2021 to 1.7 lakh tonnes in 2022 (Biswal and Johnson, 2023). This development undoubtedly presents a positive outlook for the fishing industry; however, it is critical to continue monitoring and managing fisheries to prevent overfishing and ensure the long-term sustainability of fish stocks in the region. In 2022, the catch of Indian oil sardines saw a significant increase of 188.2% compared to the previous year, with only Odisha and Gujarat experiencing a decline in catch in 2021 (ToI, 2023). West Bengal had the highest increase at approximately 38.4%, while Puducherry and Tamil Nadu saw increases of 30% and 28% respectively. Goa (63.6%), West Bengal (52.6%) and Kerala (52%) recorded the highest percentages of sustainable fish stocks, with Puducherry (71.4%), Gujarat and Daman Diu (65%) and Maharashtra (46.4%) having the highest percentages of overfished stocks. Andhra (50%), Odisha (40.7%) and Maharashtra (32.1%) had the highest percentages of recovering fish stocks (Sathianandan et al, 2021). To ensure the long-term sustainability of these fisheries and prevent overfishing, it is crucial to continue monitoring and managing them.

Table 3: Overfishing derived biodiversity loss of Indian fishes

S.No.	Fish name	Distribution	Biodiversity status	Refernecs
1.	Tuna	coastal cuisine	Yes	Esme Raji
2.	Snapper	Subtropical Region	Yes	Felipe Poey
3.	Trevally	Pacific Ocean	Yes	Peter Forsskal
4.	Barracuda	Andhra Pradesh, Kerala	Yes	Klein
5.	Pomfret	Gujrat, Orissa	Yes	Dr.C.M. James
6.	Mackerel	Kolkata	Yes	Linnaeus
7.	Sardine	Kerala, Tamil Nadu	Yes	Trevor Day
8.	Sharks	Tropical seas& Freshwater	Yes	Wolfgang Ott

4. Climate Change Impacts on Ocean Aquatic Life

Environmental invariability and long-term biodiversity change have a great influence on the ecosystems and the food production systems (Ray, 2015). The Climate change and overfishing are playing an important role in loss of biodiversity. Fish culture are interact with climate change and biodiversity, leading to profound changes in this ecosystem. Actually, Climate change is disrupting the physio-chemically and ecology of the ocean, with most significant consequences on the life. (Rashid & Travis, 2020). Additionally, the catching of essential predators such as sharks, tuna, andshardine in highly disrupt the marine biodiversity (Sanjay et al, 2024).

5. Overfishing as Loss of Fish Biodiversity in India

Fishing encompasses the use of nets, fishing methods for over capacity and unsustainable such as bottom trawling and pelagic driftnets, that catch too many fishes which are endangered. These are called By-catch. In many cases, by-catch is destroyed and thrown back into the Ocean. They also catch young fishes and prevent them from growing to reproduce.

Illegal and Unregulated Fishing activities are also affected fish biodiversity. mainly Economic and Food Needs, Lack of management and proper government fisheries rules and regulations are a key cause of overfishing produce biodiversity.

6. Loss of Biodiversity

Interesting to note the differences between temperate and tropical waters when it comes to fishing resources. While temperate and cold waters may have fewer species, the abundance of each species is often greater. In contrast, tropical waters have a greater variety of species, but each species may have a lower abundance. In the Indian waters, there are around 200 species that are currently being exploited, but it's important to note that not all of them are experiencing overfishing (Link, 2021). Many of the pelagic resources have a wide migration circuit and only a small accessible part of them is being exploited due to limitations in fishing range. It's crucial that we continue to monitor fishing practices and implement sustainable measures to ensure the long-term health of our oceans and fishing industry (Bakun, 2023). Changes in the migratory route caused by hydrological factors can lead to variations in the availability of fish in certain regions. This can result in significant fluctuations in the annual catch, which is often seen in some of the most popular pelagic fisheries, such as oil sardine, mackerel and Bombay duck (Chea et al, 2020). These three species alone account for a staggering 70% of the total pelagic catch (Paul et al, 2019). Therefore, concerns about overfishing in Indian waters are rather hypothetical, as our fishing is currently restricted to a narrow coastal region covering only a portion of the fishable area of the wide continental shelf. While there may be some local resources that have been overfished, most resources remain underexploited and there are indications that more resources can be exploited in areas where fishing has not been extended (Fu et al, 2023). Through recent exploratory operations, it has been discovered that fishing in unexplored shelf areas can significantly enhance the catch of ground fishes, leading to increased commercial yields (Hilborn et al, 2023). It is important to acknowledge the potential benefits of increased fishing yield while also prioritizing the conservation of marine resources. Covering only a fraction of the fishable area of the continental shelf of 415,000 square kilometers, it is conceivable to raise the question of overfishing in Indian waters. It is indeed true that some local resources may have been overfished, leading to a decline in their abundance. It is crucial to strike a balance between sustainable fishing practices and meeting the demand for seafood, so that future generations can also benefit from these resources (Steenson and Creedon, 2022).

II. CONCLUSION

It is crucial to be aware of the impact of overfishing on the ecosystem as it can permanently alter species' composition and biodiversity. The depletion of fish stocks and damage to marine ecosystems caused by intensive fishing practices have led to the decline of biodiversity and loss of top predators, such as sharks. Bycatch, which represents about a quarter of all marine catch, is also a significant issue that affects hundreds of thousands of sea turtles and cetaceans. Responsible fishing practices are necessary to avoid overfishing and protect the ocean and its inhabitants for future generations. overfishing is a pressing issue that requires urgent attention. To address this problem, a range of solutions should be considered. These include banishing fishing subsidies, adopting rightsbased fishery management and applying regulations on fishing nets. Protecting essential predator species, increasing marine protected areas, and imposing a ban on fishing in international waters can also contribute to reducing overfishing. Traceability standards are also important to establish if a product has been legally sourced and to support responsible value chains. By adopting these solutions, we can work towards reducing overfishing and preserving the world’s oceans. The World Trade Organization has already secured a historic deal aimed at curbing fishing subsidies and reducing global overfishing, and governments around the world should expand Marine Protected Areas. The introduction of traceability standards and a ban on fishing in international waters would also be effective overfishing solutions. Together, these solutions can help to ensure that our oceans remain healthy and productive for generations to come. Overfishing produce to various effects on biodiversity in which ecosystem destruction and imbalance, Unsustainable fishing technology is a major threat to ocean ecosystems. The destruction of the physio-chemical environments of marine life, ghost fishing and bycatch are the three main issues produced serious problem for Indian fish biodiversity.

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SUSTAINABLE PERSPECTIVES OF GREEN ENERGY TRANSITION: AN INVESTIGATION OF ORGANIC SOLAR CELLS

Abstract

Among the solar cells, organic solar cells (OSC) are being passionately investigated for their technologically appealing adds-on characteristics: flexibility, sustainability, economic and efficiency. Thin-film organic solar cells have emerged as a viable alternative to traditional silicon-based solar cells. The possibility to obtain high performance in OSC can be attained by using highly effective absorber materials and the use of inverted device structure in organic solar cells involving tandem architecture. In OSC, the polymers are generally utilized as the absorber layer to induce the light harvesting efficiency and performance of devices. The key to fulfilling the highly effective OSC is to design the new polymers with narrow bandgap and appropriate energy level arrangement. The polymers with low band gap e.g. polythiophenes, polyphenylenevinylenes and polyfluorenes are being employed to harvest solar energy. These materials exhibits high mobility, good stability, high absorption and tunable energy levels making them suitable for high-performance solar cells.

Keywords: Organic solar material, Photovoltaic Cell, Environmental Sustainability

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I. INTRODUCTION

With the growing concerns about climate change the importance of renewable energy sources, particularly solar energy, has become increasingly evident. Energy security, and the negative impacts of non-renewable sources has also fueled the research area. Renewable energy offers an environmentally friendly alternative for fossil fuel, reducing greenhouse gas emissions, air pollution. Solar energy, generated using photovoltaic panels, is a clean and widely available source of energy. Solar cells convert sunlight into electricity through the photovoltaic effect. There are various types of solar cells, starting from traditional inorganic cells to newer organic solar cells. Organic photovoltaic (OPV) cells have gained attention due to their potential for flexibility, low-cost production, and versatility. However, they currently have lower efficiencies and shorter lifetimes compared to traditional inorganic cells. Research in OPV cells are ongoing, focusing on improving efficiency, stability, and charge transport. A comprehensive review of OPV cells highlights their evolution, working principles, device structures, and performance characteristics. The chapter identifies areas for future research in OPV, including efficiency improvement, stability and development of new materials. It also focuses on optimizing morphological characteristics for charge transport. Overall, renewable energy sources, particularly solar energy, are crucial for a sustainable future, and ongoing research and development in OPV cells aim to improve their efficiency and viability.

The world is facing an unprecedented energy crisis, driven by the increasing demand for energy, the depletion of fossil fuels, and the devastating impacts of climate change. In this context, renewable energy sources have emerged as a vital component of a sustainable energy future. Renewable energy offers a cleaner and environmentally friendly alternative to non-renewable sources which is more sustainable. It can reduce the dependency on fossil fuels, increase energy security, and address the climate crisis. The primary reasons for the importance of renewable energy is its potential to address climate change. Greenhouse gas emissions from the burning of fossil fuels are a major contributor to global warming and climate crisis. The use of renewable energy can help reduce these emissions, playing a critical role in addressing the climate crisis. According to the International Energy Agency (IEA), renewable energy can reduce carbon emissions by up to 78 Giga tons by 2050, helping to limit global warming to well below 2°C.

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II. ENERGY SECURITY AND ROADMAP

Another critical reason for the importance of renewable energy is energy security. Over dependence on foreign fuel makes individuals and societies more vulnerable to disruptions in the global energy market. To ensure a stable and reliable supply of energy for the future, renewable energy sources, such as solar and wind, are the game changer. These sources are less prone to supply disruptions and can be immune to energy supply disrupted by geopolitical tensions or natural disasters. However, despite the many benefits of renewable energy, there are also many challenges associated with it. Mostly on its deployment. One of the main challenges is the cost of developing and installing renewable energy technologies, which can be higher than the cost of traditional sources. However, in the long-term costs of renewable energy are often lower due to the fact that they do not require the repeated purchase of fuels. Also, their costs are most likely to decrease as technology improves and economies of scale are achieved. Among renewable energy sources, solar energy is perhaps the most widely used. It is generated using photovoltaic panels, which convert sunlight into electricity. Solar energy is a clean, renewable source of energy that is available in abundance and can be used in a variety of applications, including electricity generation, heating, and lighting. Other benefit of solar energy is that it is relatively easy to install and maintain, and it can be used in a variety of locations, including urban, suburban, and rural areas.

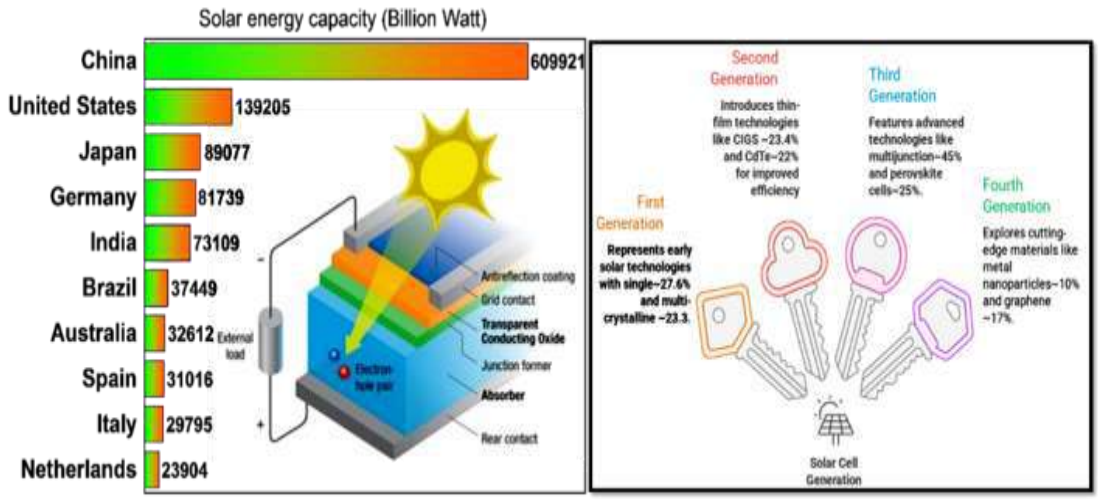

Figure 1: Solar energy harvesting performance of leading nations. Schematic diagram of solar cell. Evolution and future of photovoltaic cell.

III. ORGANIC PHOTOVOLTAIC CELLS

Photovoltaic cells, also known as solar cells, are the building blocks of solar energy. They convert sunlight into electricity through a process called the photovoltaic effect. Photovoltaic cells are made up of semiconductor materials that absorbs sunlight and releases electrons, which is used to generate electricity. There are several types of photovoltaic cells. Traditional inorganic cells made of silicon and the newer organic cells made of polymers or small molecules. Organic photovoltaic cells are a promising technology that has gained significant attention in recent years. These photovoltaic cells can also be made into a variety of shapes and sizes, making them more versatile. However, organic photovoltaic cells currently have lower efficiency rates and shorter lifetimes compared to traditional inorganic cells. Despite the challenges and limitations of renewable energy, there are many opportunities for future growth and development. In the field of renewable energy research and developments are going on with focus on improving efficiency and stability, developing new materials, and optimizing morphological characteristics for charge transport. The development of new technologies, such as floating offshore wind and advanced geothermal systems, is also expected to play a critical role in the transition to a low-carbon economy.

IV. SOLAR TECHNOLOGY IN A GLANCE: PAST, PRESENT, AND FUTURE

Photovoltaic (PV) technology has come a long way since its inception in the 19th century. From the early experiments with selenium to the modern-day solar panels, PV technology has evolved significantly over the years. In this note, we will take a historical review of PV technology and explore its future perspective. The concept of photovoltaic effect was first discovered by French physicist Edmond Becquerel in 1839. Becquerel observed that when light hits a conductive material, it generates an electric current. However, it wasn't until the 1880s that the first solar cells were developed using selenium. These early solar cells were inefficient and expensive, but they marked the beginning of PV technology. The development of silicon-based solar cells in the 1940s revolutionized PV technology. Silicon solar cells were more efficient and durable than their selenium counterparts. The first commercial solar panels were introduced in the 1950s, and they quickly gained popularity for space exploration and remote power generation. The 1960s saw a significant increase in the use of solar panels for space exploration. Solar panels were used to power satellites, spacecraft, and even the Apollo missions. The success of solar panels in space exploration led to their increased adoption for terrestrial applications, such as remote power generation and telecommunications. The 1990s saw a significant reduction in the cost of solar panels, making them more competitive with fossil fuels. The development of thin-film solar cells and concentrator photovoltaic (CPV) systems further increased the efficiency and reduced the cost of solar panels. Today, solar panels are used for a wide range of applications, from residential rooftops to large-scale solar farms. While PV technology has made significant progress, there are still challenges to be addressed:

- **Intermittency:** Solar energy is an intermittent source of energy, requiring energy storage solutions to ensure a stable power supply.
- **Cost:** While the cost of solar panels has decreased significantly, they can still be expensive for some applications.
- **Materials:** The production of solar panels requires materials like silicon, which can have environmental and social impacts.

Despite these challenges, PV technology presents numerous opportunities:

- **Renewable Energy Transition:** PV technology can play a critical role in the transition to a low-carbon economy.
- **Energy Access:** Solar energy can provide energy access to remote and off-grid communities.
- **Economic Benefits:** The solar industry can create jobs and stimulate local economies.

Organic photovoltaic (OPV) cells are a type of solar cell that uses organic materials to convert sunlight into electricity. OPV cells have gained significant attention in recent years due to their potential for low-cost, flexible, and large-area solar energy conversion. OPV cells offer several advantages, including:

- Low-cost and flexible fabrication
- Potential for large-area solar energy conversion
- Environmentally friendly materials

However, OPV cells also face several challenges, including:

- Low power conversion efficiency
- Limited stability and lifetime
- High sensitivity to environmental conditions

V. FUTURE OUTLOOK

In conclusion, renewable energy sources are critical for a sustainable energy future. They offer a cleaner, more sustainable, and environmentally friendly alternative to non-renewable sources, and can help reduce our dependence on foreign oil, increase energy security, and address the climate crisis. While there are challenges and limitations associated with renewable energy, there are also many opportunities for future growth and development. As the world continues to transition to a low-carbon economy, renewable energy is expected to play a critical role in reducing greenhouse gas emissions and mitigating the impacts of climate change. Photovoltaic technology has come a long way since its inception in the 19th century. From the early experiments with selenium to the modern-day solar panels, PV technology has evolved significantly over the years. As the world transitions to a low-carbon economy, PV technology is expected to play a critical role. While there are challenges to be addressed, the opportunities presented by PV technology are numerous, and its future perspective is bright. Organic photovoltaic cells are a promising technology for solar energy conversion. Their low-cost and flexible fabrication, potential for large-area solar energy conversion, and environmentally friendly materials make them an attractive alternative to traditional solar cells. However, OPV cells still face several challenges that need to be addressed before they can be widely adopted.

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DEFENCE MECHANISM IN PLANTS: AN INTEGRATED APPROACH TO PATHOGEN RESISTANCE

Abstract

These defense mechanisms are categorized into pre-existing (constitutive) defenses, which include structural characters and inherent biochemical properties, and post-existing (induced) defenses, which develop upon detection of pathogen attacks. Secondary metabolites, i.e., phytoalexins, phenolics, alkaloids, and terpenoids, have antimicrobial activity, whereas some primary metabolites also play their role in plant defense.In addition, plants employ systemic acquired resistance (SAR) and induced systemic resistance (ISR) to boost long-term immunity. SAR, which is mainly mediated by salicylic acid (SA), induces pathogenesis-related (PR) proteins, whereas ISR, which is controlled by jasmonic acid (JA) and ethylene (ET), boosts resistance against a wide range of pathogens. These combined self-defense mechanisms together guarantee plant survival under varied environmental conditions.

Keyword: Defense mechanisms, Pre-existing, Post-existing Structural, Biochemical,

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I. INTRODUCTION

Plants, being stationary, cannot flee from attacks by pathogens and environmental stresses. Yet, nature has provided them with structural and biochemical defense mechanisms that allow them to withstand these threats. In the majority of instances, plants are resistant to disease-causing organisms, while susceptibility is the exception. In spite of being subjected to many diseases and millions of fungal spores or bacterial cells, plant species remain alive. While some single plants might get damaged or killed, others in the population either tolerate the pathogen or are unaffected. This shows that plants are not innocent victims of pathogen attacks but instead have built-in defense mechanisms or can trigger special responses following infection, enabling them to survive in disease-laden environments. These resistance mechanisms are developed over the course of time due to genetic alteration and pre-existing resistance genes that are induced, a function of co-evolution between host plants and disease organisms. The interaction of the disease-causing organisms and host plants was noted since agriculture first began and serves as the basis for identifying disease-resistant cultivars.

Enhanced knowledge on these mechanisms laid the groundwork for the use of natural disease control practices. Furthermore, plant defense mechanisms are important in epidemiology because they affect the severity and spread of pathogen attack within a plant population. The success or failure of a plant to resist or die from a pathogen depends mostly on its genotype and that of the pathogen. For instance, cereal rust fungi infect neither chickpea nor pea plants because of genetic incompatibility. Plant cell genetic make-up decides whether the pathogen will be able to invade and produce a disease state. Plant-pathogen compatibility or incompatibility is regulated by multifaceted biochemical machinery controlled by similar genes in the two organisms. Plant disease resistance is the ability of plants to resist pathogen attack with minimal or no damage, whereas susceptibility is the reverse state, in which a plant cannot effectively defend itself. This resistance or susceptibility is a hereditary trait governed by genetic information contained in DNA molecules within the chromosomes of plant cells.

The nucleus is the control center, coordinating cellular functions, metabolism, and biochemical reactions. Moreover, mitochondrial and chloroplast DNA also takes part in the functions of a cell. Expression of plant features, such as defense mechanisms, is controlled through genes, many of which stay dormant until being activated by chemical, physical, or biological elicitors. For plant pathogenesis, disease production occurs in stages, and the defense mechanisms in plants are arranged in a corresponding manner. First, a pathogen comes to the host and finds pre-existing structural and biochemical barriers that are part of the plant's hereditary defense. If the pathogen is able to overcome these barriers, it tries to establish a parasitic relationship with the plant tissues.

The plant, in turn, triggers other defense mechanisms, creating new physical and biochemical barriers to resist disease development. Plant resistance can thus be divided into two phases: resistance to infection by the pathogen and resistance to disease initiation and tissue invasion. Both plant and pathogen use biochemical armaments, namely proteins, either to aid in infection or bolster defense. Defensive mechanisms involving structural supports and biochemical processes are critical in deciding whether the pathogen-host interaction succeeds or fails (Singh 2017).

II. PREEXISTING OR PASSIVE DEFENSE MECHANISM AS PHYSICAL BARRIERS

1. Pre-existing Structural Defenses

Plants being sessile organisms have developed different defense mechanisms against invading pathogens. A key line of defense against pathogens is pre-existing structural defense, which provides a physical barrier to hinder pathogen entry, colonization, and infection. These structures are permanently present in plants and constitute the first line of defense prior to any biochemical or molecular responses. The efficiency of these structural defense mechanisms differs with plant species and environmental factors.

a. **Wax and Cuticle:** The cuticle, which is made up of cutin and waxes, is the outermost epidermal cell layer and acts as a defense barrier. Waxes aid in defense by producing a hydrophobic surface that discourages water from adhering to it, allowing moisture not to build up on inclined plant surfaces where pathogens might adhere and infect. The cuticle is both a chemical and physical barrier against infection. In certain plant crops, a higher cuticle thickness has been connected with greater disease resistance. In some crops, for example, the outer wall of the epidermis composed of a sturdy cuticle has been connected to greater resistance towards fungal infections. Conversely, in certain plant mutants, the deficiency of surface waxes has been linked with enhanced susceptibility to infections. Also, differences in cuticle thickness between plant species have been found to affect their resistance to certain fungal pathogens. The role of the cuticle in protecting plants against disease development underscores its importance in disease prevention (Mehrotra 2017).

b. **Epidermis Layer:** The epidermis, being the outermost layer of living host cells, is significant in plant defense against microbial infection. Its strength is supported by polymers like cellulose, hemicelluloses, lignin, mineral deposits, and polymerized organic compounds, which make it resistant (Schneider *et al*., 2012). The rigidity and thickness of the outer cell wall of epidermal cells also play important roles in protecting against some pathogens by presenting a robust physical barrier (Agrios, 2005). Because of its strength, fungal pathogens are prevented from penetrating the plant material directly (Hückelhoven, 2007). Research has indicated that plant species with more thickened cell walls demonstrate higher resistance to fungal infection (Deising *et al*., 2000). But if a pathogen evades this defense, for example, through a wound, the inner plant tissues are exposed to invasion, and intact epidermal defenses are emphasized (Freeman & Beattie, 2008).

c. **Structure of Natural Opening:** Plant natural openings like stomata, lenticels, hydathodes, and nectarthodes are important sites for water movement, secretion, and gas exchange. These openings are also utilized by pathogens as entry points, leading to disease establishment in vulnerable hosts (Agrios, 2005).

Stomata are small pores located mainly on the leaves' surfaces and are protected by specialized guard cells that open and close them. Stomata facilitate gas exchange and transpiration but also serve as an entry point for fungal and bacterial pathogens. Research has shown that pathogens such as *Pseudomonas syringae* use stomatal closure to invade internal tissues (Melotto *et al*., 2006). Fungal spores of *Magnaportheoryza*e also germinate on the leaf surface and invade stomata to infect and cause the rice blast disease (Tucker & Talbot, 2001). Under attack from pathogens, plants can trigger stomatal closure as a defense mechanism, inhibiting the opportunity for infection (Zeng & He, 2010).

Lenticels are gas exchange tissues on stem, root, and certain fruit barks that allow exchange of gases between inner tissue and air. Lenticels are made up of loosely packed cells and allow diffusion of oxygen into inner tissues and release of carbon dioxide and other metabolic gases (Esau, 1977). Lenticels also provide potential sites of entry for pathogens, particularly those causing fruit rots and bacterial diseases. For instance, *Erwiniaamylovora*, the fire blight pathogen of apples and pears, can infect through lenticels and lead to disease development rapidly (Vanneste, 2000). Similarly, fungal pathogens such as Colletotrichum spp. infect through lenticels to lead to anthracnose infections (Prusky, 1996).

Hydathodes are leaf tip or margin outgrowths with glandular functions participating in exudation of surplus water as guttation. In contrast to stomata, hydathodes are open and possess a continuous pathway for microbial invasion (Buchanan *et al*., 2000). Bacterial pathogens like *Xanthomonas* spp. utilize hydathodes as a means of entry into vascular tissues and induce systemically spreading diseases like bacterial blight of rice (*Xanthomonasoryzae*pv. oryzae) (Nino-Liu *et al*., 2006). A film of water in hydathodes offers a favorable habitat for bacterial growth and migration into xylem vessels (Mew *et al*., 1993).

Nectarthodes, specialized tissues that are connected with nectaries, enable secretion of nectar to attract pollinators. The pores, however, can be entry points for infection by pathogens, particularly bacteria and fungi that are favored by high sugar content. Studies have revealed that *Erwinia* and *Pseudomonas* species have been found to infect nectarthodes and induce floral and systemic infection of cherry and citrus (Miller *et al*., 2006). Infection usually spreads through pollinators and environmental vectors to enhance disease transmission.

2. Pre-existing Biochemical Defense

Existing biochemical defense mechanisms in plants include the synthesis and storage of chemicals that inhibit the growth of pathogens and trigger resistance prior to infection (Hammerschmidt, 1999). The defensive chemicals can be secreted outside the plant into the surrounding environment or retained in the cells as a first line of defense against potential pathogens (Osbourn, 1996). Certain of the chemicals are active directly by being toxic to invading microbes, while others are active indirectly by activating useful antagonistic microflora on plant surfaces, which will exclude the settlement of pathogens (Morrissey &Osbourn, 1999).

Among these defense chemicals, constitutive antibiotics, or phytoanticipins, are already in plant tissues prior to the occurrence of a fixed concentration, providing pathogens with a level of ongoing protection (VanEtten*et al*., 1994). Wound-induced antibiotics, or phytoalexins, are, on the other hand, triggered by infection or mechanical damage and enhance the biochemical defense of the plant (Kuc, 1995). Their role in plant defense underscores their contribution to the maintenance of resistance and the limitation of pathogen colonization.

a. **Chemical Inhibitors Released by Plants in Their Environment:** Plants release various biochemical compounds into the environment that aid in disease resistance by preventing the growth of pathogens. These have been proven through research to possess inhibitors such as phenolic compounds, organic acids, and root exudates and play an active role in preventing infection and pathogen colonization (Morris *et al*., 2021).

   Research into onion smudge disease due to *Colletotrichumcircinans* confirms that onion varieties that have red scales are resistant in comparison with those with white scales. Such resistance is accomplished by the presence of catechol and protocatechuic acids, which move from the outside red scales and suppress spore germination (Zhu *et al*., 2020). In a similar manner, resistant varieties of *Cicerarietinum* (chickpea) contain an increased concentration of glandular malic acid-secreting hairs on the surface of leaves, effectively preventing spore germination of fungal in origin and inhibiting the extension of the hypha (Sharma *et al*., 2019).

   Cutin acids and waxes of plants have also been found to exhibit fungitoxic activity. Ginkgo biloba leaf cuticular wax was found to confer disease resistance against pathogen adhesion and colonization (Wang *et al*., 2022). Additional study on citrus suggests that lime's cutin acids are antimicrobial and suppress Gloeosporiumlimetticola, a pathogen of citrus diseases (Ahmed *et al*., 2021). Root exudates are also important for the defense of the plant. Flax crops have been shown to secrete glucosides on hydrolysis that give hydrocyanic acid, a chemically active compound that specifically inhibits plant pathogens like *Fusariumoxysporum* f. sp. lini but stimulates saprophytic organisms like Trichodermaviride (Patel *et al*., 2023). The biocontrol fungus T. viride produces volatile antibiotic compounds like trichodermin that are strongly inhibitory to the fungal pathogens (Singh & Mehta, 2021).

   Further evidence of root exudate-mediated resistance is also found in pea cultivars. Root exudates of pea resistant cultivars have been found to inhibit the germination of spores of certain races of *Fusariumoxysporum* f. sp. pisi, thereby limiting infection, while pathogenic races are less inhibited (Ghosh *et al*., 2022). These findings indicate the pivotal role of

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plant inhibitors in enhancing disease resistance through diverse biochemical processes.

b. Inhibitor Present in the Plant Cells before Infection: Plants contain preformed inhibitory substances responsible for their defense against a number of pathogens through inhibition of infection and pathogen growth. The biochemical compounds, such as phenolics, glucosides, and antimicrobial secondary metabolites, function as preformed barriers within plant tissue (Morrissey &Osbourn, 1999).

In potato (*Solanumtuberosum*), resistance to *Streptomyces scabies*, a potato scab causal agent, has been associated with increased levels of chlorogenic acid in tubers, which retards pathogen development (Lowe-Power *et al*., 2018). Likewise, isopimpinellin, a furocoumarin, is present in citrus lime leaves and confers resistance to*Gloeosporiumlimetticola*, inhibiting infection (Wang *et al*., 2021).

Oat (*Avena sativa*) leaves and roots yield avenacin, a fluorescent glucoside with antifungal activity that suppresses the growth of several fungal pathogens, such as *Ophiobolusgraminis*, the pathogen responsible for take-all disease in wheat (Osbourn, 2003). Yet, the pathogenic isolate *O. graminis* var. avenae, which infects oats but not wheat, secretes an enzyme known as avenacinase that deactivates avenacin's inhibitory activity, facilitating infection (Edwards *et al*., 2019). This specificity is noted for the involvement of pathogen-derived enzymes in breaching plant chemical defenses. Resistance to *Fusariumoxysporum*f.sp. *tulipae* in tulips (Tulipa spp.) is linked with high concentrations of tuliposides, which decrease towards the time of harvest, thus leaving the bulbs vulnerable to infection (Fokkens *et al*., 2020). Likewise, in pears (*Pyrus* spp.), fire blight resistance caused by *Erwiniaamylovora* is associated with the phenolic glucoside arbutin, which is hydrolyzed by β-glucosidase to yield antimicrobial compounds. The most resistant tissues to infection, e.g., floral bracts, have high β-glucosidase activity, while highly susceptible tissues like nectaries have low enzymatic activity, corresponding to higher pathogen susceptibility (Liu *et al*., 2018). In apples (*Malusdomestica*), resistant and susceptible varieties alike have phloridzin, a phloretin glucoside. Resistance is not so much correlated with the concentration of phloridzin but with the capacity of the plant to hydrolyze it.

In susceptible hosts, *Venturiainaequali*s, the apple scab pathogen, may survive under the cuticle without inducing host cell collapse for up to several days, avoiding the release of fungitoxic oxidation products that otherwise suppress the pathogen (Bus *et al*., 2011).

c. **Unavailability of the Essential Nutrients and Growth Factors for the Pathogens:** Certain pathogens are host-specific, that is, they can survive and multiply on specific plant species or varieties. This is because the host plant supplies vital nutrients and factors of growth like vitamins, amino acids, polypeptides, and enzymes. Mutant plant varieties in certain situations lack these vital factors of growth and nutrients, making it inhospitable for pathogen existence and infection. Therefore, such varieties can show resistance by inhibiting pathogen establishment. Nutrient availability, especially nitrogen levels, is also important for disease development. Low levels of nitrogen will inhibit disease development, while high levels of nitrogen will favor disease development by increasing the growth of pathogens and susceptibility of plants (Mahawer *at al.*,2022).

3. **Post-existing Structural Defense**

a. **Suberization:** Suberization is a plant structural defense where suberin, a water-repelling polymer, is deposited during pathogen attack (Lulai, 2007). Suberin deposition creates a barrier surrounding infected cells and hinders the spread of pathogens and the entry of nutrients (Schreiber *et al*., 2005). Suberin deposition is essential in wound repair, sealing wounds, and avoiding microbial infections (Thomas *et al*., 2007). It also has a role in the development of protective cork layers, as in potato soft rot (*Rhizopus* sp.), potato scab (*Streptomyces scabie*s), and necrotic lesions in tobacco caused by tobacco mosaic virus (Dean &Kuc, 1985). Suberization promotes plant resistance to biotic stress and is an active response to environmental stress (Kolattukudy, 1981). Its function in plant defense is crucial in resistance to disease and in providing structural strength in stressful conditions (Bernards, 2002).

b. **Cork Surface Formation:** Outside of the site of infection, plant pathogens induce their host to create more than one layer of cork cells as a means of defense). These layers of cork limit the pathogen in the initial lesion while inhibiting the spread of toxic chemicals it can produce. They also reduce the pathogen's access to necessary resources by inhibiting water and nutrient movement from healthy tissue to the infected tissue. Consequently, patches of dead tissue are characterized as necrotic. During certain host-pathogen relationships, healthy tissue below the necrotic patches effectively removes the pathogen from the host. For instance, resistant clones of plants limit fungal development by forming ligno-suberized border zones, composed of three or six suberized cell layers, which prevent Seiridiumcardinale spread in cankers of cypress trees (Agrios, 2005)

c. **Tyloses:** Tyloses are protoplast outgrowths from nearby living parenchymatous cells that invade xylem vessels in half-bordered pits and cause vessel blockage. They are important in plant defense because they can either restrict pathogen spread or induce wilt by clogging water conduction. The rate and scope of tyloses formation have implications regarding whether they are protective or disease-promotive. In sweet potato, wilt caused by *Fusariumoxysporum* f. sp. *batatas* is in some varieties resisted by the formation of rapid and profuse tyloses, which inhibits the spread of the pathogen. The same defensive functions of tyloses have also been noted in vascular wilt of tomatoes (Mehrotra 2017).

d. **Formation of Abscission Layers:** The development of an abscission layer makes it easy for plants to shed mature fruits and senescent leaves. This is a layer with gaps between the infected and normal tissues as opposed to cellular organization. These gaps occur when the middle lamella of a single or double cell layer that girdles the infected region breaks down. Consequently, the infected tissue becomes unsupported, slowly dehydrates, dies, and ultimately separates from the plant. This process prevents the dissemination of pathogens by isolating and eliminating the infected area along with a few surrounding, uninfected cells, thus limiting further damage (Ritesh 2022).

e. **Gum Disposition:** Some plants form gum at the edge of injured tissue as a resistance response to pathogen penetration. The deposits of gum act as an isolating barrier that effectively separates diseased tissue from healthy tissue. It cuts off the pathogen's access to nutrients, eventually starving it and killing it. Research has indicated that resistant rice cultivars have gum accumulation within lesions, especially under infections by *Helminthosporium* sp. and *Magnaporthegrisea*, the leaf spot and blast disease pathogens, respectively (Singh, 2005).

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f. **Sheathing of Hyphae:** Penetrating hyphae are usually covered with a protective sheath created by the outgrowth of the cell wall, which serves to limit pathogen extension. The nature of this sheath is not well understood, but it can be made up of cellulose, callose, or other materials. In certain cases, the sheath seems to be a cytoplasmic deposit and not a direct cell wall modification. Furthermore, lignitubers may also develop as outgrowths on the inner cell wall surface at the penetration site of fungi. In some instances, the penetrated cell wall becomes swollen and may be suberized or lignified as another mode of additional plant defense (Mehrotra 2017).

g. **Lignification:** Lignified cell walls serve as a tough defense barrier against invasion by hyphae, hindering free movement of nutrients and eventually starving the pathogen. This has been seen in plants like radish, which shows resistance against *Peronosporaparasitica* and *Alternaria japonic*a, and in potatoes, where lignification serves to limit *Phytophthorainfestans* infection (Mahawer 2022).

4. Post-existing Biochemical Defense

a. **Phytoalexin:** Phytoalexins are antimicrobial low-molecular-weight compounds de novo produced by plants following attack by a pathogen. They are secondary metabolites that restrict the growth of fungi, bacteria, and viruses and play a significant role in plant defense (Hammerschmidt, 1999). In contrast to pre-formed defense chemicals, phytoalexins are not formed until recognition of the pathogen and concentrate at the infection site, creating a chemical barrier to invading pathogens (Ahuja *et al*., 2012).

Various plant species yield different phytoalexins. Camalexin is the major phytoalexin in *Arabidopsis thalian*a, whereas brassinin occurs in Brassica species (Glawischnig, 2007). Glyceollins in *Glycine max* (soybean) defend against fungal pathogens, while resveratrol in grapes confers resistance to *Botrytis cinerea* (Jeandet*et al*., 2002). These phytoalexins interfere with pathogen metabolism, damage membrane integrity, and trigger oxidative stress, resulting in pathogen death (Pedras*et al*., 2011).

Phytoalexin production is controlled by plant signaling networks, primarily salicylic acid, jasmonic acid, and ethylene (Zhou *et al*., 2010). Biosynthesis of their production is typically initiated by pathogen-

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associated molecular patterns (PAMPs) and elicitors from the attacking microorganisms (Morrissey and Osbourn, 1999). This quick action assists plants in limiting pathogen colonization and infection spread.

b. **Pathogenesis-related (PR) Proteins:** Pathogenesis-related (PR) proteins are important in plant defense against pathogens by preventing pathogen development, breaking down their cell walls, and triggering systemic resistance responses. PR proteins are expressed in response to biotic and abiotic stresses such as infection by fungi, bacteria, and viruses (van Loon *et al*., 2006). PR proteins consist of 17 families according to their structure and function, which include chitinases, β-1,3-glucanases, thaumatin-like proteins, and peroxidases (Sels*et al*., 2008).

Chitinases and β-1,3-glucanases break down fungal cell walls, hindering pathogen invasion (Mauch*et al*., 1988). Defensins and thionins destabilize microbial membranes, arresting pathogen growth (Broekaert*et a*l., 1995). Certain PR proteins, like PR-1, have antifungal activity, although their precise mechanism is unknown (van Loon and van Strien, 1999). PR proteins are stored in infected and adjacent healthy tissues, offering localized and systemic resistance (Ryals*et al*., 1996).

The first PR proteins were reported in tobacco plants that had been infected with tobacco mosaic virus (Gianinazzi *et al*., 1970). Since that discovery, they have been discovered in numerous plant species and are viewed as being central to the innate immunity of plants. They tend to be controlled by signaling molecules including salicylic acid, jasmonic acid, and ethylene (Glazebrook, 2005).

c. **Plant Defense through Antifungal Proteins:** Antifungal proteins (AFPs) are a critical part of plant defense, conferring resistance against fungal pathogens by inhibiting spore germination, interfering with fungal membranes, and breaking down fungal cell walls (Selitrennikoff, 2001). AFPs are generally induced by fungal infection and are an important component of plant immunity.

Among the highly characterized AFPs, chitinases and β-1,3-glucanases are enzymes that can hydrolyze chitin and glucans, the principal molecules of fungal cell walls, inhibiting fungal growth (Mauch *et al*., 1988). Defensins and thionins show direct antifungal action through disruption of plasma membranes of fungi, resulting in ion leakage and cell death (Thomma *et a*l., 2002). Other AFPs, i.e., thaumatin-like proteins and lipid transfer proteins, affect fungal metabolism and suppress the extension of hyphae (Van Loon *et al*., 2006).

Plant signalling molecules such as salicylic acid, jasmonic acid, and ethylene regulate these proteins to bring forth a synchronized action against fungal infection (Glazebrook, 2005). Different plant species contain AFPs in the form of wheat, rice, tobacco, and Arabidopsis, as indicated by the conserved aspect of their roles in plant resistance (Gao *et al*., 2000). They are also utilized to make transgenic crops more fungal-resistant.

d. **Defense through Pathogen Enzyme and Toxin Inactivation:** Plants defend themselves against pathogens by inactivating the enzymes and toxins of the pathogens and preventing infection and disease development. Pathogens release enzymes like pectinases, cellulases, and proteases to break down plant cell walls and promote invasion (Walton, 1996). In turn, plants generate protein inhibitors such as polygalacturonase-inhibiting proteins (PGIPs) that limit the function of fungal polygalacturonases and slow down cell wall degradation (De Lorenzo et al., 2001). Analogously, protease inhibitors repress pathogen-derived proteases from degrading plant defense proteins (Ryan, 1990). Pathogens also produce toxins to interfere with plant metabolism and suppress immunity. Plants respond to such toxins by the production of detoxifying enzymes like glucosyltransferases that modify and detoxify toxic molecules (Pedras *et al*., 2011). Oxidative enzymes like peroxidases and laccases also break down pathogen toxins, lowering their toxic impact (Hammerschmidt, 1999). Certain plants synthesize anti-toxin proteins that bind pathogen-derived toxins, preventing them from binding to cellular targets (Rogers *et al*., 2011).

These mechanisms of defense are essential for plant survival and are controlled through signaling molecules like salicylic acid and jasmonic acid (Glazebrook, 2005). Through the inactivation of pathogen enzymes and toxins, plants successfully inhibit infection and boost resistance.

e. **Phenolics in Plant Defense:** Phenolic compounds are vital in plant defense against pathogens since they function as antimicrobial compounds, structural components, and signal molecules. They are secondary metabolites such as flavonoids, tannins, lignins, coumarins, and phenolic acids that make contributions to both pre-existing and induced resistance processes (Nicholson and Hammerschmidt, 1992).

One of the critical functions of phenolics is their antimicrobial property, which inhibits the development of fungi, bacteria, and viruses. For instance, phytoalexins, which are a type of phenolics, build up in response to infection by pathogens and interfere with microbial metabolism (Dixon, 2001). Phenolic acids such as ferulic and caffeic acids also reinforce the cell wall by cross-linking with lignin and other structural polymers to make it resistant to enzymatic breakdown by pathogens (Bhuiyan*et al*., 2009).

Phenolics are also involved in the oxidative burst, producing reactive oxygen species (ROS) that are responsible for pathogen inhibition and hypersensitive response (HR)-induced cell death (Sanchez-Vallet*et al*., 2010). In addition, salicylic acid, a phenolic compound, is a critical signaling molecule in systemic acquired resistance (SAR), augmenting long-term plant immunity (Durrant and Dong, 2004).

5. Molecular Defense Mechanism in Plants

Plants have developed advanced molecular defense systems to resist infection by pathogens and abiotic stresses. These defenses are active at the cellular and molecular levels and utilize intricate networks of signals to detect danger and mount the right defense. Pattern-triggered immunity (PTI) and effector-triggered immunity (ETI) are the main molecular defense systems in plants, both of which are critical for plant survival.

a. **Pattern-Triggered Immunity (PTI):** PTI is the primary molecular defense in plants and is triggered by the perception of pathogen-associated molecular patterns (PAMPs). PAMPs are microbial molecules that are conserved across species, including bacterial flagellin, fungal chitin, and lipopolysaccharides (Jones and Dangl, 2006). These molecules are sensed by pattern recognition receptors (PRRs) on the plant cell surface, which trigger defense responses.

   Upon PAMP recognition, PRRs trigger intracellular signaling cascades that lead to the generation of reactive oxygen species (ROS), activation of mitogen-activated protein kinases (MAPKs), and defense-related gene upregulation (Boller and Felix, 2009). These reactions make plant cell walls more rigid through callose deposition, increase antimicrobial metabolite production, and trigger stomatal closure to seal off pathogen entry.

b. **Effector-Triggered Immunity (ETI):** ETI is a more specialized defense response that is initiated when plants recognize pathogen effectors—pathogen-secreted proteins that inhibit PTI. Plants have developed resistance (R) proteins to sense these effectors and induce a more effective immune response (Dangl *et al*., 2013).

   ETI tends to provoke a hypersensitive response (HR), a programmed cell death (PCD) at the point of infection that limits pathogen spread. ETI also initiates systemic acquired resistance (SAR), a pre-arming of distant tissue for subsequent infection (Durrant and Dong, 2004). It is mediated systemically by the plant hormone salicylic acid (SA) and plays an important role in defense signaling.

c. **Plant Defense Signaling Pathways:** Molecular defense responses are controlled by three main signaling pathways mediated by salicylic acid (SA), jasmonic acid (JA), and ethylene (ET):

   - **SA Pathway**: Triggered in the case of biotrophic pathogen infections (e.g., *Pseudomonas syringae*), SA signaling enhances SAR and expression of pathogenesis-related (PR) proteins with antimicrobial activity (Vlot *et al*., 2009).

   - **JA Pathway:** Usually activated in response to necrotrophic pathogens (e.g., *Botrytis cinerea*) and herbivores, JA signaling triggers the accumulation of defense molecules such as protease inhibitors and secondary metabolites (Wasternack and Hause, 2013).

   - **ET Pathway:** Frequently interacts synergistically with JA in the control of defenses against both biotic and abiotic stresses, promoting cell wall strengthening and antimicrobial protein accumulation (Broekaert*et al*., 2006).

d. **RNA Silencing and Epigenetic Defense:** Plants are also employing RNA interference (RNAi) to destroy viral RNA and halt virus replication. Small interfering RNAs (siRNAs) are important for silencing viral genes (Ding, 2010). Epigenetic changes such as DNA methylation and histone modification also control defense gene expression upon pathogen attack.

III. CONCLUSION

The increasing world population and extensive use of chemical pesticides to control plant diseases have raised serious issues about their harmful impacts on human health and the environment. This emphasizes the necessity of sustainable alternatives for enhanced crop productivity and quality. Studies show that an in-depth study of plant-pathogen interactions and innate plant defense mechanisms can offer novel solutions. The use of plant defense mechanisms, including induced resistance and the targeted use of plant-derived secondary metabolites, can revolutionize pest control practices. The integration of these natural defense mechanisms into sustainable crop protection strategies* can drastically minimize reliance on synthetic pesticides. Further research efforts to unravel the molecular mechanisms of plant immunity are essential for the development of effective, environmentally friendly methods of agricultural disease management.

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ORGANIC WASTE DECOMPOSITION AND VERMICOMPOST QUALITY BASED COMPARATIVE ANALYSIS OF *EISENIA FETIDA* AND *PERIONYX CEYLANENSIS*

Abstract

The increased accumulation of organic waste by way of high urbanization and cultivation rates has generated serious environmental concerns, which have prompted the need for sound and sustainable solid waste management practices. Vermicomposting, a microbe-earthworm bioprocess, has been a focus of keen interest as a 'green' process for organic waste recycling into a useful compost. This study evaluates the decomposition performance and quality of two earthworm species, *Eisenia fetida* and *Perionyx ceylanensis,* based on the most critical parameters such as nutrient level, organic matter reduction, and microbial activity. The objective is to determine which species performs better in decomposing organic waste and producing high-quality compost for enriching soil and plant growth.

A controlled vermicomposting experiment was conducted using a suitable mixture of biodegradable wastes, including kitchen residues, crop residues, and garden refuse. The waste was preconditioned and subjected to vermicomposting for a standardized period of time, under optimal temperature, moisture, and aeration levels. Regular sampling was performed in order to research the physicochemical properties

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of the vermibed, e.g., content of total nitrogen (N), available phosphorus (P), and potassium (K), degradation of organic carbon, C/N ratio dynamic changes, variations of pH, humification indices. Microbiological analyses highlighted enzymatic activity, bacterial and fungal diversity, as well as plant growth-stimulating microorganisms.

Both E. fetida and P. ceylanensis greatly stimulated organic matter decay and nutrient conversion based on the findings. But P. ceylanensis possessed a higher rate of organic matter degradation and lower final C/N ratio, indicating greater microbial activity and compost maturity.

Keywords: Eisenia fetida, Perionyx ceylanensis, Organic Matter Reduction, Microbial Activity

I. INTRODUCTION

Emergence of higher generation of organic wastes as a consequence of the pace of rapid urbanization and agriculture activities becomes severe environmental hazards. Waste handling technologies like landfilling and burning produce increased levels of pollution as well as resources-depleting impacts. Vermicomposting is an efficient process and eco-solution of disintegrating organic wastes into quality nutrient-rich compost. It's a microbiological breakdown of earthworms for decomposition of organic residue and thus, enriches the fertility of the soil to the extent that sustainable agriculture ensues.
The two most well-researched species among the numerous earthworm species employed in vermicomposting are *Eisenia fetida* and *Perionyx ceylanensis*. These are known for their efficiency in breaking down organic wastes as well as resulting in improved compost. *Eisenia fetida*, or red wiggler, is a preferred vermiculture species as it tolerates numerous organic substrates and effective waste breakdown. However, *Perionyx ceylanensis*, which is a tropical earthworm species, has also shown promising findings in organic matter

degradation and nutrient enrichment of compost. Few comparative studies exist regarding it, however, that compare the performance of these two species under the same conditions for vermicomposting.

The present study is intended to evaluate the efficacy of *Eisenia fetida* and *Perionyx ceylanensis* in organic waste degradation and vermicompost quality produced based on important parameters such as nutrient value, organic matter reduction, and microbial activity. This study aims to identify the most suitable species of earthworm that performs well in sustainable waste management according to the standards of decomposition rate, NPK content, microbial population, and enzymatic activity of vermicompost. The results of this study will improve the vermicomposting process and support the recycling of organic wastes for agriculture and environmental benefits.

Increasing generation of organic wastes through accelerated urbanization and farming is threatening the environment gravely. Open environmental practices such as waste dumping in landfills and incineration reduce the pollution conditions and channel the resources further. Vermicomposting has been viewed as a secure and sustainable technique for converting organic waste into compost packed with fertilizer. Vermicomposting is a microbial process of decomposition where the microorganisms the earthworms are affiliated with, as well as the earthworms themselves, decompose the organic matter, thereby increasing the quality of the soil as well as sustainable agriculture.

Eisenia fetida and *Perionyx ceylanensis* are well researched among the numerous earthworm species applied in vermicomposting for their ability to degrade organic waste and yield quality compost. *Eisenia fetida*, or red wiggler, is a traditional species in vermiculture for its versatility to use various organic substrates and its effective breakdown of waste.

II. REVIEW LITERATURE

Vermicomposting is gaining widespread usage as a green approach to organic waste management. It employs earthworms and microbial action to break down organic waste and turn it into nutrient-rich compost. Among the many species that have been researched for composting capability, *Eisenia fetida* (red wiggler) and *Perionyx ceylanensis* stand out for their adaptability and effectiveness.

This section addresses earthworm activity in vermicomposting, contrasts different species in terms of their effectiveness, and examines key factors controlling quality of compost including microbial input in decomposition.

Earthworms: Nature’s "Ecosystem Engineers"

Earthworms are referred to as "ecosystem engineers" because of their ability to change the structure of soil, enhance the movement of nutrients, and enhance the decomposition process of organic matter (Edwards &Arancon, 2004). By their action of feeding, they create fine organic matter particles, which enhance microbial colonisation and enzyme activity (Domínguez et al., 2010). Earthworms' species diversity and feeding tolerance also play an important role in vermicomposting efficiency (Suthar, 2009).

Comparing the Efficiency of *Eisenia Fetida* and *Perionyx Ceylanensis*

The composting capabilities of different species of earthworms have been researched intensively.

- **Red Wiggler (*Eisenia Fetida*):** Commended for high reproductive rate, extreme environmental factor tolerability, and immense ability to degrade organic wastes (Edwards & Bohlen, 1996). Research shows that vermicomposting process matures through E. fetida to enhance the nutrient value of the vermicompost (Gupta & Garg, 2009).

- ***Perionyx Ceylanensis*:** This earthworm is tropical and has shown superior waste decomposition ability. Research has established that P. ceylanensis degrades waste at a higher rate, generates more biomass, and yields more cocoons compared to E. fetida (Suthar & Singh, 2008).

A comparative study by Yadav et al. (2019) revealed that P. ceylanensis produces vermicompost with a reduced carbon-to-nitrogen (C/N) ratio and higher microbial activity, and hence it is better for faster stabilization of compost.

Determining Vermicompost Quality: The nutrient value, which is more or less the quality of vermicompost, is comprised of nitrogen (N), phosphorus (P), potassium (K), and significant micronutrients (Garg et al., 2006). Mineralization of nutrients and conversion to plant available forms is the function of the earthworms (Kumar et al., 2010).

- **E. fetida Impact:** Aira et al. (2007) demonstrated that E. fetida increases the nitrogen content of compost through the stimulation of microbial growth.
- **Advantage of P. Ceylanensis:** Experiments reveal that P. ceylanensis vermicompost is richer in NPK density and decays organic materials faster than that of E. fetida compost (Sinha et al., 2010).

The C/N ratio is a critical indicator of compost maturity, with a lower ratio showing higher stabilization. Evidence indicates that P. ceylanensis compost achieves a lower C/N ratio, hence more suitable for use in agriculture (Yadav & Tare, 2021).

The Microbial Factor in Vermicomposting: Microorganisms play an important role in breaking down high-molecular weight organic matter to low-molecular weight, accessible nutrients (Pathma & Sakthivel, 2012). Earthworms activate the microbial populations through the provision of conducive environments to helpful bacteria and fungi in gut and castings (Edwards et al., 2011).

- Jayakumar et al. (2013) noted that P. ceylanensis compost contained much greater microbial activity than E. fetida compost, leading to more effective decomposition of organic matter.
- Dehydrogenase enzyme activity, a primary indicator of microbial metabolism, was also high in P. ceylanensis compost, reflecting greater biological activity (Prakash et al., 2019).

Growth and Reproduction: Sustainability in Vermicomposting: The stability of a vermicomposting system depends on the growth and reproductive ability of earthworms. From studies, P. ceylanensis reproduces faster, possesses higher biomass, and has greater cocoon deposition than E. fetida (Gajalakshmi et al., 2005). It is hence most suitable for large-scale vermicomposting plans.

III. OBJECTIVE OF THE STUDY

Explore the role played by microbes in vermicomposting, and we can discuss the populations of fungi and bacteria and their enzyme activity. It helps us know how microbial populations evolve and thrive throughout the course of composting.

Significance of the Study: Microbial activities play an important role in vermicomposting, as bacteria and fungi decompose organic matter, release nutrients, and improve the quality of compost.
The current study is important in many ways:

This research enhances the quality of vermicompost through the study of microbial processes and population dynamics, which outlines how bacterial and fungal populations contribute to the stability, maturity, and nutrient status of vermicompost, thereby adding its worth to agriculture.

Interpreting the Function of Enzymatic Activity - Enzymes like dehydrogenase, cellulase, and phosphatase are instrumental in decomposing organic matter. Enzymatic activity measurement is used to establish the efficiency of microbial activity in nutrient cycling and stabilization of organic waste.

Enhancing Earthworm Selection for Vermicomposting -Different earthworms produce different impacts on microbial diversity. In this research, the species, Eisenia fetida or Perionyx ceylanensis, which will provide a more active and more desirable microbial population, is established, thus simplifying the process of choosing the most suitable species for large-scale vermicomposting.

Boosting Sustainable Waste Management – Increasing microbial interaction in vermicomposting enables more effective recycling of organic waste, reduces landfill waste, and encourages sustainable waste management.

Improving Soil Health and Crop Yield on Farms – Microbe-enriched vermicompost increases the fertility of the soil by developing microbial diversity and nutrient availability. The findings of this research can be useful to farmers, agronomists, and ecologists by enhancing sustainable soil management practices.

This research adds to the existing literature on vermicomposting by detailing microbial processes for the breakdown of organic wastes, thereby guiding future researchers to develop improved composting methods.

IV. METHODOLOGY OF THE STUDY

The work in this investigation has the purpose of exploring microbial activity and population structure in vermicompost under the influence of bacterial as well as fungal populations along with enzymatic activity. Experimental work includes the inclusion of the following necessary steps:

1. **Experimental Design**
   - **Vermicomposting Units:** Different vermicomposting units will be maintained for treatment of the organic material using *Eisenia fetida* and *Perionyx ceylanensis*.
   - **Substrate Composition:** A mixture of biodegradable organic wastes such as vegetable wastes, cow manure, and farm wastes will be utilized as feed.
   - **Experimental Duration:** Experimental duration will range from 8 to 12 weeks to facilitate sufficient time for microbial action.
   - **Environmental Parameters:** Temperature (25–30°C), humidity (60–70%), and aeration will be provided to foster microbial and earthworm action.

2. **Acquisition of Specimens**
   - **Vermicompost Sampling:** Sampling will be done at intervals (e.g., weeks 2, 4, 8, and 12) to assess microbial activity over time.
   - **Triplicate Specimens:** Three replicates per treatment will be used to ensure reliability and accuracy.

3. **Microbial Analysis**
   - Serial dilution and the spread plate technique will be used to determine the total bacterial and fungal count.
   - Bacterial counts will be performed on nutrient agar, while potato dextrose agar (PDA) will be utilized for fungal growth.
   - Colonies will be counted and expressed as colony-forming units per gram (CFU/g) of vermicompost.
   - **Microbial Identification:** Biochemical tests (e.g., catalase, oxidase) and Gram staining will be used for bacterial identification.
   - Fungal species will be determined on the basis of morphological characteristics and lactophenol cotton blue staining.

4. **Enzymatic Activity Assessment**
   - **Dehydrogenase Activity (DHA):** Microbial respiration as an index of metabolic activity will be assessed by the triphenyl tetrazolium chloride (TTC) assay.
   - **Cellulase Activity:** Dinitrosalicylic acid (DNS) test will be used to study cellulose degradation in vermicompost.

- **Phosphatase Activity:** p-nitrophenyl phosphate (pNPP) test will examine phosphate mineralization activity.

V. RESULTS ANALYSIS

Analyzed Key Parameters:
Population of fungi and bacteria (CFU/g)
Dehydrogenase activity (DHA) (µg TPF/g/day)
Cellulase activity (mg of glucose released per gram per hour)

Phosphatase Activity (µg PNP/g/h)

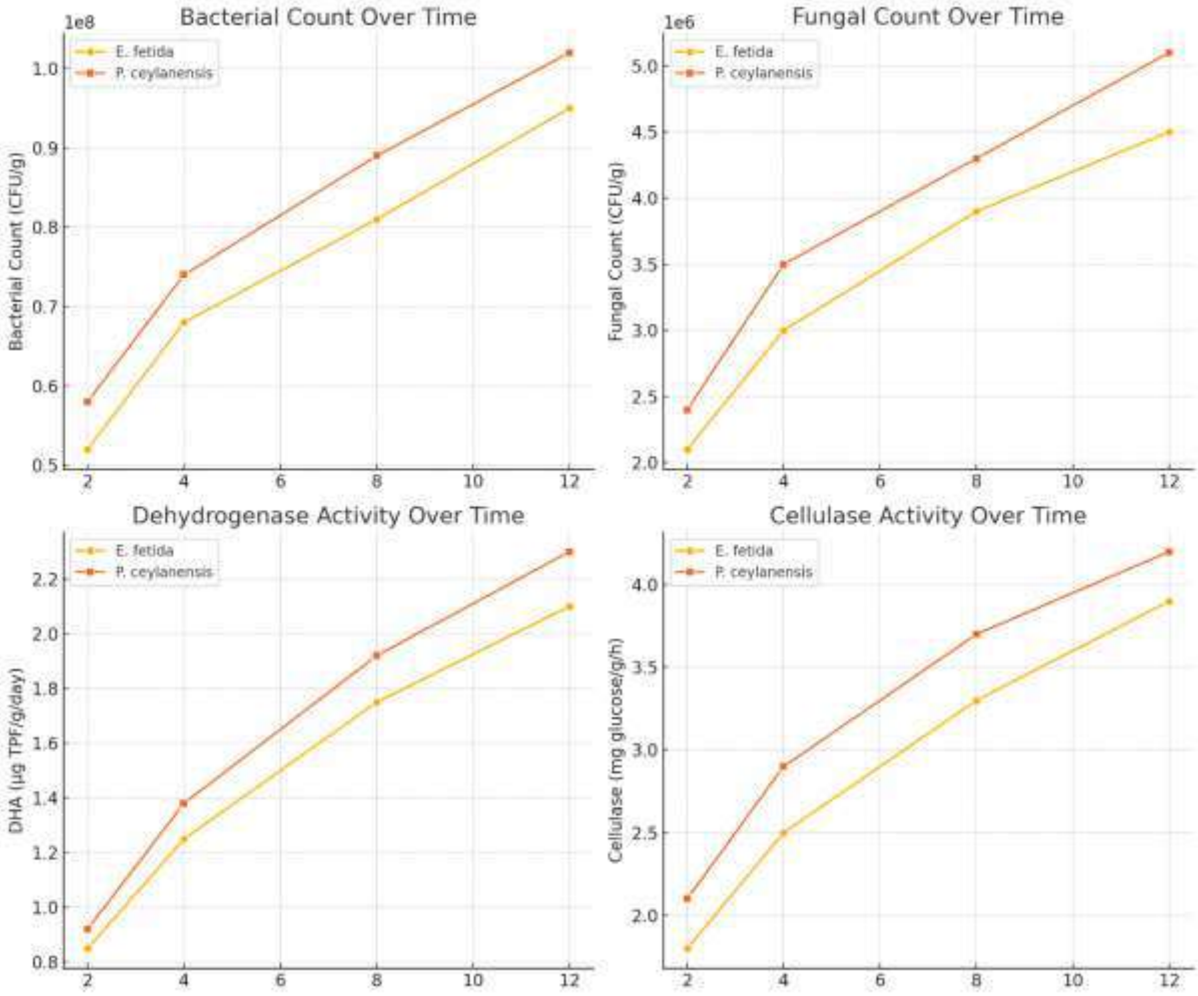

Figure 1

The study of microbial population dynamics and activity in vermicompost produced by *Eisenia fetida* and *Perionyx ceylanensis* shows significant trends over 12 weeks. The main findings are summarized in the above table and shown in the graphs.

1. **Dynamics of Microbial Populations**
   - The bacterial numbers of P. ceylanensis always were higher than E. fetida throughout the entire study duration.
   - The bacterial community always grew in both treatments, indicating favorable conditions for microbial growth.
   - The fungal numbers of P. ceylanensis were higher than those of E. fetida.
   - Both species had an increasing growth of fungal communities over time, reaching 12 weeks.

2. **Enzymatic Activity Dehydrogenase Activity (DHA)**
   - DHA, a key to total microbial metabolic activity, remained higher in P. ceylanensis treatments throughout.
   - The activity increased steadily, reflecting better microbial performance in the degradation of organic matter.
   - **Cellulase Activity:** Increased cellulase activity was observed in P. ceylanensis, reflecting better cellulose degradation ability.
   - The activity was highest at 12 weeks, reflecting active lignocellulosic degradation.
   - **Phosphatase Activity:** Phosphatase activity, necessary for phosphorus mineralization, was evident to a greater degree in treatments with P. ceylanensis.
   - The temporal rise refers to the decomposition of organic materials and mineralization of nutrients that occurs gradually.

VI. CONCLUSION

The results show that P. ceylanensis is more effective in decomposing organic waste compared to E. fetida, particularly in microbial growth and enzymatic activity. The high microbial population and enzymatic activity under P. ceylanensis treatments suggest that it can be a more effective species for vermicomposting in terms of nutrient release and decomposition of organic waste. Both species significantly increase the microbial growth and enzymatic activity during the vermicomposting process.

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CLIMATE CHANGE AND ITS RIPPLE EFFECT: CHALLENGES FOR FISH AND SUSTAINABLE FISHERIES

Abstract

Climate change is causing profound disruptions to fishery resources, with a far-reaching impact on aquatic ecosystems and the livelihoods that depend on them. Rising ocean temperatures, ocean acidification, and shifting weather patterns are altering fish distribution, reproductive cycles, and overall biodiversity. These environmental changes threaten the stability of both marine and freshwater fisheries, leading to declining fish stocks, habitat degradation, and increased vulnerability for fishing communities. The ripple effect of climate change extends beyond ecological impacts, affecting global food security, economic stability, and the sustainability of fisheries worldwide. This paper focuses on the multifaceted challenges climate change poses to fish populations and sustainable fisheries. It explores how environmental stressors impact species migration, reduce fishery productivity, and disrupt traditional fishing practices. Furthermore, it emphasizes the need for adaptive management strategies to reduce these effects and sustain fishery resources. Key approaches discussed include ecosystem-based fisheries management, climate-resilient policies, and the fusion of scientific

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research with indigenous knowledge. By understanding the cascading effects of climate change, we can implement adaptive solutions to safeguard fish populations, protect biodiversity, and ensure the future sustainability of fisheries in a rapidly changing climate.

Keywords: Climate change, Fishery resources, Aquatic ecosystems, Biodiversity, Habitat degradation, Adaptive management

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I. INTRODUCTION

Climate change is one of the most critical environmental challenges of the 21st century, influencing ecosystems, biodiversity, and human societies worldwide. Current scientific projections indicate that climate change will substantially modify the structure and functioning of ecosystems worldwide (Hoegh-Guldberg et al., 2019). Development agencies, such as the International Fund for Agricultural Development (IFAD) and the World Bank, have identified climate change as one of the major global threats to humanity today (IFAD, 2007; World Bank, 2010). Anthropogenic activities have accelerated significant changes in the Earth's climate system, particularly through the combustion of fossil fuels, deforestation, and industrialization. In 2017, the global average surface temperature rose to 1 °C above pre-industrial levels (IPCC, 2018). Without significant reductions in greenhouse gas emissions, global temperatures are projected to rise beyond 1.5 °C and possibly even 2 °C by the end of this century (IPCC, 2021). As global temperatures continue to rise, significant environmental shifts have been recorded across both regional and global levels (IPCC, 2021). These changes have profound effects on aquatic environments, which are particularly vulnerable to variations in temperature, chemistry, and weather conditions. The ripple effect of climate change refers to the cascading impacts that extend beyond direct physical changes, affecting biological systems and human livelihoods. Among the most affected sectors are fisheries, which are crucial for food security, economic stability, and biodiversity conservation. The increasing global temperature, ocean acidification, and extreme weather events have significantly altered aquatic ecosystems, disrupting fish populations and the livelihoods dependent on them. These changes pose serious challenges to sustainable fisheries management, requiring urgent adaptation and mitigation measures. This chapter explores how climate change influences fish populations and fisheries, highlighting key challenges and proposing sustainable solutions.

II. IMPACT OF CLIMATE CHANGE ON AQUATIC ECOSYSTEMS

1. **Rising Water Temperatures:** One of the most immediate impacts of climate change is the increase in global sea and freshwater temperatures. Water temperature is a critical environmental factor for fish, as they are ectothermic organisms whose physiological processes are significantly influenced by thermal conditions. Temperature affects various biological functions, including molecular and cellular activities, organ system functions, and overall body performance (Brett, 1971; Fry, 1971). It is a key factor in controlling essential activities such as feeding, digestion, locomotion, physical growth, reproductive processes as well as immune system responses (Brett & Groves, 1979). Warmer waters can lead to:
    - Changes in fish metabolism and reproduction. Some species may grow faster in warmer temperatures, while others experience reduced growth and survival rates.
    - Migration shifts, where fish move toward cooler regions, disrupting existing fisheries (Cheung et al., 2010).
    - Coral bleaching, which affects reef-dependent species and fisheries (Hughes et al., 2017).
    - Cod populations in the North Atlantic have declined due to rising temperatures, impacting commercial fisheries (Pershing et al., 2015).

2. **Ocean Acidification and Its Impact on Marine Organisms:** The increase in atmospheric carbon dioxide (CO_2) is absorbed by the ocean, lowering the pH of seawater. Increased carbon dioxide (CO_2) emissions have led to ocean acidification, lowering pH levels in marine waters. Approximately 25% of CO_2 generated by anthropogenic activities is absorbed by ocean waters, which accelerates the process of acidification (Eakin et al., 2008). As a result, the average ocean alkalinity has declined from 8.2 to 8.1, representing a 30% increase in acidity (IPCC, 2007b). This shift in ocean chemistry poses significant threats to marine ecosystems, particularly calcifying organisms that rely on stable pH levels for shell and skeleton formation. This affects:
    - Shell-forming organisms such as mollusks and crustaceans, which are vital to food chains (Fabry et al., 2008).

- Acidification affects the sensory functions and behavior of fish, impairing their ability to recognize predators (Munday et al., 2009).
- Acidification threatens the sustainability of fisheries, particularly those reliant on shellfish, such as the oyster industry in the United States and Canada.

3. **Rising Sea Levels and Habitat Destruction:** The melting of polar ice and the thermal expansion of seawater due to global warming are key drivers of rising sea levels, which pose a major threat to coastal habitats. As sea levels continue to rise, habitat loss may reduce biodiversity and affect fish populations that depend on these environments. Sea level rise around the UK coast at a rate of approximately 1.4 mm/year during the 20th century (Woodworth et al., 2009; UKMMAS, 2010). Additionally, rising sea levels raise salinity levels in estuaries and freshwater systems, creating challenges for species that depend on stable salinity conditions. Key habitats under threat include:
   - Mangroves and estuaries, which are essential breeding and nursery grounds for many fish species (Duke et al., 2007).
   - Freshwater habitats, where saltwater intrusion disrupts fish populations (Haines et al., 2006).

4. **Extreme Weather Events and Ecosystems Disruption:** Climate change intensifies the frequency and severity of extreme weather events, which affect fish populations and fisheries infrastructure like storms, surges, floods and droughts. These events destroy aquatic habitats, displace fish populations and reduced river flow affects migratory species, such as salmon, by limiting access to spawning grounds. Storms, hurricanes, and cyclones have become more frequent and intense, leading to:
   - Damage to fishing infrastructure, including boats, harbors, and fish farms (IPCC, 2019).
   - Changes in fish availability due to altered ocean currents and nutrient cycles.
   - For instance, hurricanes in the Gulf of Mexico have severely impacted shrimp and tuna fisheries.

III. EFFECTS OF CLIMATE CHANGE ON FISH POPULATIONS

Climate change directly impacts aquaculture by altering fish distribution, growth, and survival, while indirectly affecting ecosystem structure, productivity, and market dynamics (Adhikari et al., 2018). It also intensifies threats to freshwater ecosystems by disrupting hydrological and biological processes, making species adaptation and habitat connectivity crucial (Markovic et al., 2017). Future water security remains uncertain, depending on warming effects, water demand, and the success of climate adaptation strategies (Koutroulis et al., 2018).

1. **Changes in Species Distribution:** Warming waters force fish species to move to cooler areas, often leading to conflicts between nations over fishing rights (Pinsky et al., 2018). This shift can lead to the reorganization of marine ecosystems and disrupt existing fishing zones. In many cases, traditional fishing grounds may experience a decline in native species, while other areas may see an influx of new species. These changes can create international tensions over access to shifting fish stocks. For example, the migration of mackerel into Icelandic waters has created disputes between Iceland and the European Union.

2. **Disruption of Reproductive Cycles:** Reproduction in many fish species is closely linked to specific environmental cues, particularly temperature. Changes in water temperature caused by climate change can alter spawning seasons, leading to mistimed reproduction and reduced breeding success. Climate change disrupts these cycles, leading to reduced breeding success. Mismatched food availability for larvae (Brander, 2007). This mismatch, often referred to as a trophic mismatch, can significantly impact larval survival rates and reduce recruitment into adult populations, ultimately threatening the stability of fish stocks.

3. **Food Web Instability:** The foundation of aquatic food webs, such as phytoplankton and zooplankton, is highly sensitive to changes in temperature and chemical composition. As plankton populations decline due to warming waters, fish populations that depend on them also suffer. This disrupts entire marine food webs (Beaugrand et al., 2002). Disruptions at this foundational level can cascade throughout the ecosystem, leading to declines in species abundance, altered predator-prey relationships, and reduced fishery yields.

IV. REGIONAL IMPACTS OF CLIMATE CHANGE ON FISHERIES

The influence of climate change on fisheries is not uniform across the globe. Regional differences in environmental conditions, fishery types, and socio-economic dependency on aquatic resources contribute to varied impacts. The following studies illustrate how specific regions are facing unique climate-related challenges in their fisheries.

1. **Coral Reef Fisheries in the Pacific:** The decline of coral reefs due to warming and acidification has reduced fish populations that rely on reef habitats (Hughes et al., 2017).

2. **Arctic Fisheries and Melting Ice:** As Arctic ice melts, new fishing grounds are opening, but the ecological impacts are uncertain (Christiansen et al., 2014).

3. **Freshwater Fisheries and Drought in Africa:** Prolonged droughts have reduced water levels in lakes and rivers, impacting freshwater fisheries like those in Lake Chad (FAO, 2020).

V. CHALLENGES FOR SUSTAINABLE FISHERIES

1. **Declining Fish Stocks:** Overfishing, combined with climate change, has caused significant reduction in global fish populations. Many commercially valuable species, such as cod and tuna, are struggling to maintain stable numbers due to environmental changes, including habitat degradation, rising sea temperatures, and unsustainable fishing practices (Pauly et al., 2005). These pressures reduce reproductive success and disrupt natural recovery, threatening the long-term viability of key fisheries.

2. **Socioeconomic Challenges:** Many coastal communities across the world heavilly depend on fisheries for income, employment, and nutrition. Declining fish stocks threaten their livelihoods. Sea food serves as a primary protein source for millions worldwide, especially in developing nations, making the decline of fishery a direct threat to global food security (FAO, 2020).

3. **Governance and Policy Gaps:** Managing fisheries in a rapidly changing climate requires flaxible, science-based policies but many existing policies are often outdated or insufficient. International collaboration is essential for shared stock management and the establishment of dynamic marine protected areas. Effective governance is needed to regulate fishing quotas based on changing fish populations. Implement marine protected areas (Sumaila et al., 2011).

VI. STRATEGIES FOR ADAPTATION AND MITIGATION

Sustainable fisheries requires an integrated approach that combines both adaptation and mitigation strategies to address environmental challenges, especially those resulting from climate change, pollution, and overfishing. The proper incorporation of fisheries and aquaculture into the national climate change policy, along with strong political commitment to its implementation, is key for effective climate change adaptation and mitigation. The aim of mitigation is to reduce the long-term environmental impacts of fisheries, while adapting fisheries to climate change requires a deeper knowledge of the necessary, ongoing, and feasible adaptations, as well as those that require additional support to address current and future challenges in the industry. This approach ensures the sustainability of fisheries while safeguarding livelihoods and food security in the country (I. Magawata and J.K. Ipinjolu, 2014).

1. **Sustainable Fisheries Management:** Implementing ecosystem-based management (EBM) can help protect fish stocks and marine biodiversity (Pikitch et al., 2004). Key measures include minimizing bycatch and advancing fishing gear technologies to promote responsible harvesting practices.

2. **Climate-Resilient Aquaculture:** Developing environmentally sustainable aquaculture practices is essential for reducing dependency on wild fish populations, which are increasingly vulnerable to climate-related stressors. Using climate-smart aquaculture techniques, such as selective breeding for heat-resistant species (De Silva & Soto, 2009). Furthermore, integrated multi-trophic aquaculture (IMTA) systems and low-carbon technologies can enhance resilience, reduce environmental impacts.

3. **Global Policy and Collaboration:** Enhancing the effectiveness of international agreements such as the Paris Agreement and the United Nations Sustainable Development Goals (SDG 14) is crucial for addressing the global impact of climate change on fisheries. Supporting local and small-scale fisheries with climate adaptation funds.

VII. CONCLUSION

Climate change presents severe challenges for fish populations and sustainable fisheries. Rising temperatures, ocean acidification, extreme weather, and habitat destruction are altering marine and freshwater ecosystems. These changes not only threaten biodiversity but also put at risk the livelihoods of communities that depend on fisheries for food and income.

Adapting to these challenges requires a combination of sustainable management, climate-resilient aquaculture, coordinated policy responses, scientific innovation, community engagement and strong international cooperation. Governments, scientists, policymakers, and fishing communities must collaborate to develop and implement policies that promote long-term sustainability. Strengthening research and monitoring efforts to understand climate impacts on fisheries is essential for informed decision-making. Additionally, reducing emission of greenhouse gas and adopting low-carbon economies will play a key role in mitigating the long-term effects of climate change on global fisheries. Ultimately, building resilience in fisheries and aquatic ecosystems will require a global commitment to sustainability, innovation, and adaptation. By taking proactive measures and fostering international cooperation, we can protect fish populations, support fishing communities, and ensure that fisheries continue to supply food and economic security for future generations in the face of climate change.

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IMPORTANCE OF BOTTLEGOURD AND MANAGEMENT AGAINST ALTERNARIA BLIGHT DISEASE CAUSED BY *ALTERNARIA CUCUMERINA* (ELLIS&EVERH)

Abstract

Bottle gourd, also known as white flowered gourd and calabash gourd (Lagenaria siceraria (Molina) Standl.), is a significant cucurbit cultivated globally for its soft fruits This vegetable is an abundant source of vitamins, iron, and minerals, making it an excellent choice for individuals with digestive issues. The pulp has a cooling and bile-reducing effect. Alternaria leaf spot and Alternaria leaf blight are damaging fungal diseases affecting cucurbit crops. A significant level of seed invasion, moisture levels of the seed, duration of storage, and the existing range of temperature influence the development of seed-borne fungi. The pathogen is consistently found externally and internally, leading to seed abortion, necrosis, or seedling loss, along with negative impacts on plant growth. To ensure successful seedling development, a seed treatment involving priming and soaking in hot water can be performed.

Keywords: Bottlrgourd, Leaf spot disease, Alternaria, Survival & Management.

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I. INTRODUCTION

Bottle gourd, also known as white flowered gourd and calabash gourd (*Lagenaria siceraria* (Molina) Standl.), is a significant cucurbit cultivated globally for its soft fruits (Arvind *et al.,* 2011). It can be grown during both the rainy and summer seasons. L. siceraria is primarily cultivated in tropical regions worldwide, including India and several African nations. It has been reported to have a chromosome number of 2n = 2X = 22 (Mayura *et al.,* 2009). This annual, vigorous climbing species is monoecious and predominantly cross-pollinated, exhibiting a vast genetic diversity around the world. Yetisir *et al.* (2008) extensively summarized the collection and characterization of 162 accessions of bottle gourd germplasm obtained from 15 surveys conducted in southern Turkey. Mladenovic *et al.* (2012) examined the landraces of bottle gourd from the Balkan Peninsula and compared them to those from Africa, Asia, and America. They found that the reduction in trait variation among bottle gourds was attributed to a preference for specific shapes and sizes of the fruit.

India is home to a significant diversity of genetic variability concerning fruit shape and size (Sivaraj and Pandravada, 2005; Peter *et al.,* 2007) and is recognized as one of the centers of diversity as per de Candolle (as cited in Chadha and Lal, 1993). However, limited efforts have been made to document the variability of various traits in germplasm within India. Mathew *et al.* (2000) examined 28 accessions from different regions of India regarding their variability and concluded that they represent a valuable gene sanctuary for bottle gourd that can be utilized.

Bottle gourd is a crop that relies on cross-pollination, and well-drained sandy loam soil is ideal for its cultivation. It thrives in soil with a pH of 6.0–6.7, although it can also withstand alkaline soils with a pH of 8.0. Approximately 3-4 kg of seeds are needed to cultivate one hectare of land. A spacing of 2.0-2.5m between rows and 45-60cm between plants is highly recommended. The optimal sowing periods are February-March, June-July, and November-December. During the summer months, it requires 6-7 irrigations, totaling 9 irrigations overall.

Nutritional Value

This vegetable is an abundant source of vitamins, iron, and minerals, making it an excellent choice for individuals with digestive issues. The pulp has a cooling and bile-reducing effect. The oil from the seeds is used externally to relieve headaches. The fruits contain 0.2% protein, 2.9% carbohydrates, 0.5% fat, and 11 mg of vitamin C per 100 g of fresh weight. The fruit has a moisture content of 96.3%, mineral matter at 0.5%, calcium at 0.002%, and phosphorus at less than 0.01%. Other minerals found include iron (0.7 mg/100 g), sodium (11.0 mg/100 g), potassium (86.0 mg/100 g), and iodine (4.5 mg/kg). The bottle gourd's leaves contain cucurbiticin, vitamin B, vitamin D, and small amounts of vitamin E. Vegetables play a crucial role in supporting human health, maintaining the body's alkaline balance, and preventing diseases, thanks to their rich content of carbohydrates, minerals, and vitamins. The fruits can be utilized as a vegetable or in sweet dishes. When used as a vegetable, it is easily digestible, even for patients (Thamburaj and Singh, 2000).

Principle	Nutrient Value	Percent of RDA
Energy	14 Kcal	<1%
Carbohydrates	3.39 g	2.5%
Protein	0.62 g	1%
Total Fat	0.02 g	0.5%
Cholesterol	0 mg	0%
Dietary Fiber	0.5 g	1%
Vitamins		
Folates	6 µg	1.5%
Niacin	0.320 mg	2%
Pantothenic acid	0.152 mg	3%
Pyridoxine	0.040 mg	3%
Riboflavin	0.022 mg	2%
Thiamin	0.029 mg	2.5%
Vitamin A	16 IU	0.5%
Vitamin C	10.1 mg	17%
Electrolytes		
Sodium	2 mg	<1%
Potassium	150 mg	3%
Minerals		
Calcium	26 mg	2.6%
Copper	0.034 mg	4%
Iron	0.20 mg	2.5%
Magnesium	11 mg	3%
Manganese	0.089 mg	4%
Phosphorus	13 mg	2%
Selenium	0.2 mg	<1%
Zinc	0.70 mg	6.5%

Source: USDA National Nutrient database

Maigandi and Ngang (2002) stated that the aim of this study is to assess the proximate composition, amino acid profile, and mineral content of the whole seed, dehulled seed, and seed coat of *Lagenaria siceraria* to offer insights into its nutritional values.

Ghule *et al.* (2007) stated that traditional healers suggest bottle gourd juice for issues like flatulence, diabetes, high blood pressure, liver problems, and as a diuretic. Deshpande *et al.* (2008) found that it is integral to complementary and alternative therapies, and in India, there is a common practice of consuming a glass or two of freshly made juice on an empty stomach. Although extracts from bottle gourd show some positive effects in animal models, there is a scarcity of studies conducted on humans. In contrast, Puri *et al.* (2011) noted several severe adverse effects of consuming bottle gourd juice, especially when it is bitter.

Ghule *et al.* (2009) noted that bottle gourd helps prevent excessive sodium loss and diminishes fatigue, particularly in the summer months. It's a low-calorie diet, ideal for men suffering from diabetes and jaundice. The fruits possess therapeutic properties and serve as cardiotonics, aphrodisiacs, hepatoprotective agents, analgesics, anti-inflammatories, expectorants, diuretics, and antioxidants.

Garcia-Mas *et al.* (2012) noted that among vegetable crops globally, Cucurbitaceae holds the second position, following Solanaceae in economic significance. The bottle gourd (*Lagenaria siceraria*) plant is a widespread legume that remains largely underutilized in many tropical and subtropical countries. In sandy or loamy soil, the plant can be cultivated from seeds. It can serve as a low-growing ground cover or as a climbing plant; in that scenario, some support might be required for the ripening fruits. The plant is frequently cultivated in the Sudan savanna region of Nigeria, particularly in Zamfara State, where it is grown as a commercial crop. Its fruits serve as both containers and musical instruments, while the seeds act as a thickener for soup similar to "egusi" and provide edible oil.

Symptoms

Typical symptoms initially manifest as small, round, and light to reddish-brown marks, which subsequently grow in a concentric fashion. Lesions frequently merge to create larger necrotic regions, and in the center of the area, olivaceous sporulation takes place. Up to now, data regarding the management of Alternaria leaf blight in bottle gourd under hot arid conditions is limited **(Maheshwari *et al.*, 2017).**

Thomma (2003) noted that they are cosmopolitan molds and are present in soils, plants, fruit, feed, and indoor air. The Alternaria genus comprises saprobes and plant pathogens known to have infected crops globally in the field, leading to the decay of numerous plant products post-harvest. Species of Alternaria are frequently observed on small grains, leading to reductions in production and processing yields.

Ostry (2008) mentioned that Alternaria spp thrive, owing to their ability to grow at low temperatures. They are widely recognized post-harvest pathogens that cause food deterioration during refrigerated transport and storage. Kumar *et al.* (2011) stated that Bottle gourd is a significant vegetable within the cucurbitaceous family. Bottle gourd thrives optimally in the warmer regions of the globe. Bottle gourd possesses numerous medicinal properties. Latin *et al.* (1994) indicated that Alternaria leaf blight can result in 30% yield losses and can also adversely affect the dissolved substances in the fruits.

Neeraj and Verma (2010) indicated through a survey that Alternaria leaf spot predominantly affects bottle gourd, bitter gourd, ridge gourd, and ash gourd. *Alternaria cucumerina* and *Alternaria alternata* impact cucumbers worldwide. The spores can travel through the air over long distances, as well as via rain and warm, humid conditions (60-80%) that are ideal for disease progression. Under these weather conditions, plant yields may also decline.

Verma and Verma (2010) indicated that most Alternaria spp. pose a threat to various crops worldwide, leading to different disease types. Of all the diseases, the Alternaria leaf spot on bottle gourd is the most severe, caused by *Alternaria cucumerina*. This pathogen was isolated from the sick leaves of the bottle gourd, as well as from the infected, shriveled seeds, which were small, had brown spots on the surface, and exhibited low germination potential.

Meena *et al.* (2010) stated that Alternaria leads to significant yield reductions in crops, with symptoms showing dull dark-colored spots. The blemishes appearing on the leaves additionally feature concentric circles on the leaves. After a while, the smaller spots connect to the larger ones, creating curves in the process. Once Alternaria leaf blight is present, seeds should be sown after appropriate treatments, and if planting occurs early, deep wrinkling may be performed.

Marraiki *et al.* (2012) indicated that leaf spot ailments are caused by Alternaria spp. It poses greater challenges for the spinach crop, leading to Alternaria leaf spot in spinach. In Saudi Arabia, spinach's Alternaria leaf spot was initially documented in 2009. The mortality rate of the disease was determined to be 80%. The spinach leaf spot began in October and stayed elevated from November through January.

Sarbhoy and colleagues (2006) documented the Cercospora leaf spot affecting cucurbits. It is brought about by *C. citrulina*. The cercospora is a notable issue among all the diseases, making it challenging to harvest the jug gourd because of the cercospora leaf spot. It was first documented by Mukhtar *et al.* (2013) in Pakistan.

Zitter *et al.* (1996) mentioned that Alternaria leaf spot and Alternaria leaf blight are damaging fungal diseases affecting cucurbit crops. A significant level of seed invasion, moisture levels of the seed, duration of storage, and the existing range of temperature influence the development of seed-borne fungi. The pathogen is consistently found externally and internally, leading to seed abortion, necrosis, or seedling loss, along with negative impacts on plant growth. To ensure successful seedling development, a seed treatment involving priming and soaking in hot water can be performed.

Ellis *et al.* (1971) noted that the identification of Alternaria spp. is straightforward due to their morphological characteristics and the presence of conidia. Conidia are shaped as single, ellipsoidal, chains, and multi-celled, exhibiting a light brown hue. The species can be distinguished by their diagonal and longitudinal septa.

Meena *et al.* (2002) indicated that blight disease is among the most prevalent diseases caused by the genus Alternaria, resulting in average yield loss. Symptoms of this illness consist of inconsistent gray to deep brown leaf patches featuring pronounced lines inside the spots on the foliage. The round spots frequently merge to create extensive areas that result in the decay of the leaves. In various instances, small dark-colored spots appear on tender twigs and pods (Valkonen and Koponen, 1990). To effectively manage Alternaria blight, it is important to sow clean certified seeds that have been properly stored and to do so early after deep ploughing. Additionally, clean cultivation, timely weeding, and maintaining an optimal plant population, along with avoiding irrigation during flowering and pod formation stages, are essential steps to follow.

Morphological Characters

Ph.B. Gannibal (2011). Isolated conidia were produced on the agar surface. The typical dimensions of conidia ranged from 70 to 94 µm in length and 22 to 25 µm in width, while the conidial beak measured between 40 and 145 µm. Overall, these measurements fall within the size range established by Simmons (2007) for *Alternaria cucumerina* on Potato Carrot Agar, where the conidial body measured smaller at 43-70X16-20 µm, while the beak was significantly longer, ranging from 70-220X284 µm.

Sharma and colleagues, (2018). The infected samples were gathered from Northern Madhya Pradesh to assess variability among twenty-five collected isolates of *Alternaria cucumerina* var. *cyamopsidis*, the causative agent of Alternaria blight in Clusterbean, focusing on conidial morphology and cultural variability on Potato dextrose agar medium. Among the twenty-five isolates, five isolates: isolate A displayed white with a light olive black center, isolate B had a dark olive grey hue with a white center, isolates C and E were dark black and brown in color, respectively, while isolate D exhibited a dark olive black colony with a brown fluffy edge. Based on the growth of mycelium, the isolates were observed to differ from one another. The longest conidial length was observed in isolate B (114.72 µm), while the conidial width was also recorded in isolate B (7.0 µm). The isolate of D showed the highest count of horizontal and vertical septa, measuring 7.16 µm and 4.48 µm, respectively. The isolate B exhibited the greatest radial growth of the colony, measuring 88.4 mm. Variability research is crucial for recording the changes within populations and individuals, as variability in morphological and physiological characteristics can signify the presence of distinct pathotypes.

Survey

Singh *et al.* (2009) stated that growing resistant or tolerant varieties is among the most effective strategies to reduce losses caused by disease incidence. To identify or develop a resistant variety, having sources of resistance is essential. Resistant sources could exist in the native cultivars, local varieties, traditional cultivars, semi-wild relatives, and related species of the vegetable crops.

Mark *et al.* (2005) reported that Hannahs Choice F1 was identified as a resistance source against powdery mildew, Fusarium race 2, and potyviruses in muskmelon. Resistance sources have been identified in wild taxa like Abelmoschus crinitus, A. moschatus, A. angulosus, and A. pungens of okra against Cercospora blight. Borkar and Umaharan (2007) stated that discovered resistant cowpea genotypes, namely. IT97K-1069-8, IT97K-556-4 associated with Alternaria leaf spot. Singh and Gurha (2007) evaluated various genotypes/varieties of mung bean and discovered that 5 genotypes (BM 4, CO 4, CO 5, ML 515, and TM 9850) exhibited resistance to Alternaria leaf spot induced by Alternaria sp.

Kimber and Paul (2011) indicated that all varieties of faba bean sold commercially were vulnerable to Alternaria leaf spot. Chauhan and Bhatia (2013) reported screening 22 germplasm lines/cultivars of bottle gourd for resistance, discovering that lines like GH 3 and GH 9 demonstrated resistance to anthracnose disease.

Maheshwari *et al.* (2015) stated that growing resistant or tolerant varieties is among the most effective methods to reduce losses caused by diseases. During the rainy seasons of 2011 and 2012, seventeen bottle gourd varieties/genotypes (Pusa Naveen, Pusa Samridhi, Udaipur Local, Pusa Santushti, Pusa Sandesh, PSPL, Chomu Local, Azad Harit, Panchmahal Local, Arka Bahar, Thar Samridhi, PN 22, DBG 5, DBG 6, Jodhpur Local, IC 567538, and Sriganganagar Local) were assessed for their resistance to Cercospora leaf spot in the hot arid field environment of Rajasthan. Among the tested varieties, no variety was immune or resistant; four varieties (Pusa Naveen, Pusa Santushti, Pusa Samridhi, and Pusa Sandesh) displayed moderate resistance, while four others (PSPL, Arka Bahar, PN22, and DBG6) showed moderate susceptibility, leaving nine varieties categorized as susceptible.

Vivekanand *et al.* (2018), Thirteen types of bottle gourd were assessed for their resistance to downy mildew disease during the rabi season of 2017 at the Horticultural Instructional-cum Research Farm, College of Agriculture, IGKV, Raipur, Chhattisgarh. Out of the thirteen varieties tested, three namely. Amrit, Ankit, and Anmol were unaffected by the disease and demonstrated an immune response to downy mildew. Two (Manya, Ns-433), four (Chutki, Haruna, Latto, and Naveen), and three (Angad, Mahima, and Sarita) strains exhibited resistance, moderate resistance, and moderate susceptibility, respectively. One variety (Divya) was vulnerable to the disease, and no variety was identified as highly vulnerable.

Cause and Disease Development

Deshwal *et al.* (2004) mentioned that *Alternaria cucumerina* induces leaf blight and survives in the soil as a saprophyte on decaying crop remnants. When wind and splattered water transferred conidia from infected plants to vulnerable tissues, it propagated from one plant to another. Germinating spores can directly invade the host and also enter through wounds and natural openings. Moist environments and elevated temperatures are perfect for the onset of illnesses. Alternaria has been observed to affect all above-ground sections of the plants, including stems, leaves, fruits, pods, and flowers. A detailed, comparative overview of the morphological variation in cucurbit, brassica, and solanaceae crops across different species of Alternaria.

Khalid *et al.* (2004) reported that the incidence of disease escalates at all temperatures as the duration of leaf wetness extends. The highest recorded average severity of disease was at 180C following 24 hours of wetness duration. Ahamad *et al.* (2000) observed that the disease manifested in early July, with its peak intensity occurring when temperatures were between 25 and 28°C and the average relative humidity exceeded 80%. Precipitation was deemed largely accountable for the level of infection and the onset of illnesses.

Matharu *et al.* (2006) reported that the disease developed on radish leaves within a temperature range of 15-25°C and a relative humidity of 100% for 10-12 hours.

Media

Sharma and colleagues, (2018). Alternaria blight is the most prevalent and destructive illness caused by *Alternaria cucumerina* var. cyamopsidis in Clusterbean. This fungus thrives in Potato dextrose agar and Tomato dextrose agar mediums in in vitro conditions. The development of the fungus was evaluated using fifteen distinct media. PDA seemed to be superior to other media for the development of *Alternaria cucumerina* var. cyamopsidis. The characteristics of fungus growth, including colony color and sporulation, varied across different culture media. The fungus colony had a dark brown hue.

Separation

Ellis *et al.* (1971) noted that identifying Alternaria spp is straightforward due to their morphological characteristics and the presence of conidia. Conidia are shaped as single, ellipsoidal, chain-like, and multicellular structures, featuring a light brown hue. The species can be distinguished by their diagonal and longitudinal septations.

Alternaria was first identified by **Nees (1816)** using A. tenuis as its sole species. Features of the genus consisted of the formation of dark-hued phaeodictyospores in chains and a beak with tapering terminal cells. Von Keissler (1912) combined A. tenuis and Torula alternata (Fries, 1832) under Alternaria alternata, owing to uncertainties in Nees's description of A. tenuis.

Singh and Singh (2003) examined cultural differences among five isolates of Alternaria triticina, the pathogen responsible for wheat leaf spot. They noted considerable differences concerning mycelial development, coloration, conidia length, conidiophore emergence pattern, conidia shape, and their germination.

Kumar (2004) noted differences in culture and physiology among various isolates of Alternaria triticina in wheat. Sharma and Pandey (2012) studied three isolates of A. burnsii that lead to blight in cumin. All three isolates exhibited differences in their pathogenic behavior. The isolate Ab-1 was discovered to be very pathogenic on cumin cv. GC-4 exhibited a disease intensity of 46.17 percent under artificial inoculation, followed by Ab-3 at 43.72 percent and Ab-2 at 37.39 percent. Saharan and Kadin (1983) noted significant differences in virulence across the races of Alternaria brassicae that lead to leaf spot and blight in crucifers. Castro *et al.* (2000) investigated pathogenic variability among Alternaria solani isolates in greenhouse settings on tomato plants and found that the isolates varied in virulence across 14 tomato genotypes.

Martinzer *et al.* (2002) also discovered pathogenic variability in isolates of Alternaria solani, which causes early blight in tomatoes.

Shekhawat *et al.* (2013) investigated cultural, morphological, and pathogenic diversity in five isolates of Alternaria burnsii, the organism responsible for cumin blight. All the isolates showed considerable differences in percentage of disease intensity, radial growth, and conidial morphology, with the briefest latent period and most severe disease.

Pathogencity

Bassimba and Mira (2012) demonstrated pathogenicity in 3-month-old fennel plants by applying a conidial suspension of A. petroselini (103 conidia / ml of water). Control plants were treated exclusively with sterile distilled water. Plants were wrapped in plastic bags and placed in a growth chamber for 72 hours at 25°C. Infantino *et al*. (2009) likewise demonstrated pathogenicity on mature fennel plants by applying a conidial suspension of A. petroselini (10^5 conidia/ml).

Survival

Pawar *et al.* (2014) reported that the disease is more severe when there is high atmospheric moisture over 90% and elevated temperatures during the growing season.

Sultana *et al.,* (2010). The recovery of field fungi such as Alternaria spp., Cladosporium spp., and Fusarium spp. diminished after 3-6 months of storage, while the occurrence of storage fungi like Aspergillus flavus and A. niger peaked between 6 and 24 months of storage.

Chemical Control

Singh *et al.* (2001) one of the most efficient ways to manage the disease caused by Alternaria is the proper use of fungicides. The efficacy of Mancozeb in managing early blight in tomatoes. Mancozeb also demonstrated effectiveness as a seed treatment, succeeded by Thiram, Bavistin, and Iprodione.

Maheshwari *et al.* (2017) described the handling of Alternaria leaf blight of bottle gourd during a field trial conducted in the rainy seasons. Various fungicides and biological agents are employed to manage the Alternaria leaf blight affecting bottle gourd disease. Seventeen distinct treatments employed for this aim include a 0.1% carbendazim combined treatment, 0.25% mancozeb, 5.0% pseudomonas fluorescens, and 5.0% neem leaf extracts applied as treatments. At the conclusion of the trials, the findings indicated that neem leaves at 5.0% were the most effective in managing the Alternaria leaf blight disease of bottle gourd, achieving a maximum disease control of 78.23%.

Javadian *et al.* (2014) stated that ethanol extracts exhibit an antimicrobial effect against Streptococcus pyogenes, Streptococcus pneumonia, and Streptococcus saprophyticus. The impacts can be assessed using a micro dilution method. The outcomes of plant extracts show the highest inhibition of the disease. The Sesamum indicum with ethanol extracts exhibited the highest efficacy in disease control, while Satureja hortensis with ethanol extracts demonstrated the least inhibitory effects.

Mahesh and Satish *et al.* (2008) described the antimicrobial properties of various plant extracts such as Acacia nilotica, Sida cordifolia, Tinospora cordifolia, Withania somnifera, and Ziziphus mauritiana using methanol against Bacillus subtilis, E. coli, P. fluorescens, S. aureus, and X. axonopodis. They possess antifungal properties as well. A. nilotica leaf extract demonstrating the highest antibacterial effectiveness against B. subtilis. The extract from both leaf and root demonstrates significant effectiveness in managing the disease. A. nilotica leaf extract exhibits a broad spectrum of anti-fungal effects against A. flavus.

Mekuria *et al.* (2005) recorded the application of plant extracts as a raw material; they represent new sources of fungicides and promote resistance to pest pathogens. Organic pesticides are the focus of attention today. Various types of phytochemicals are utilized in crop protection. A study was conducted on 17 extracts of bryophytes due to their potential anti-fungal properties in both in vivo and in vitro conditions. Sphagnum quinquefarium, Bazzania trilobata, Dicranodontium, Diplophyllum albicans, and Hylocomium splendens exhibit a 50% inhibition rate in managing the mycelial growth of Botrytis cinerea and Alternaria solani. B. trilobata also diminishes the severity of Phytophthora infestans disease in tomato plants. Thus, bryophyte extracts represent the most effective natural solutions for managing plant pathogens.

Khair and Haggag (2007) investigated that early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*) are the primary diseases that impact the vegetative growth of the potato. A total of 9 medicinal plant extracts are utilized after being sun-dried including onion seeds (*Allium cepa*), garlic oil (*Allium sativum*), peppermint leaves (*Mentha piperita*), eucalyptus leaves (*Eucalyptus globulus*), lemon foliage (*Cymbopogon citratus*), chili fruits (*Capsicum frutescens*), and tulsi leaves (*Ocimum basilicum*). The extracts from these medicinal plants were evaluated in vitro for their effectiveness against *P. infestans* and *A. solani.*

Egel and Harmon (2001) noted the use of fungicides in managing the Alternaria leaf blight in muskmelon. To manage the Alternaria leaf blight disease, chlorothalonil was applied using two different types of spray nozzles: a flat-fan nozzle and a hollow nozzle for spraying. The findings indicated that unsprayed controls exhibited a greater disease severity in comparison to the other sprayed treatments. The type of nozzle likewise did not influence the severity of the disease or the crop yield. Therefore, there are no variations in disease management based on any method of spray application.

Prasad and Naik (2003) indicated that under in vitro conditions, Iprodione and Mancozeb were effective among non-systemic fungicides, while thiophanate methyl was effective among systemic fungicides. Singh and Singh (2006) stated that they evaluated the effectiveness of seven fungicides, including chlorothalonil, copper oxychloride, azoxystrobin, propineb, copper hydroxide, mancozeb, and hexaconazole, at concentrations of 2500, 2000, 1000, 500, and 250 ppm, specifically targeting A. Alternate, the pathogen responsible for tomato blight, using concentrations of 1000, 500, 200, 100, and 50 ppm. Our results indicated that every fungicide significantly decreased the fungal radial growth. Nonetheless, hexaconazole proved to be highly effective as it resulted in complete growth inhibition of 100%.

Katiyar *et al.* (2001) noted that optimal control of Alternaria leaf spot disease in bottle gourd was achieved by applying 0.2% Indofil M45, followed by Chlorothalonil, Cuman L, Ridomil, Indofil Z-78, Copper oxychloride, Jkstein, and Topsin-M.

Singh and Rai (2003) discovered that Indofil M-45 and Kavach are the most effective in limiting the growth of A mycelium. Alternata brinjal in vitro infection prior to treatment with Bavistin and Thiram.

Sidlauskiene *et al.* (2003) found Amistar to be highly effective in managing Alternaria leaf spot in cucumbers, cabbages, and tomatoes, decreasing disease incidence by 88-93 percent, while Euparen plus Bion was noted to enhance biological efficiency.

Singh and Singh (2002) reported that three applications of 0.25% Dithane M-45 outperformed other fungicides such as Kavach, Foltaf, Bayleton, Baycor, and Contaf 5 EC regarding extra yield. They recommended three applications of Dithane M-45 (0.25%), Kavach (0.1%), or Foltof (0.25%) at 10-day intervals for farmers to control A. brassicicola on cabbage.

Mei *et al.* (2007) found that the chitosan derivatives of sulfanilamide exhibited significant inhibitory effects on A. solani at concentrations ranging from 50 to 500 μg/ml. The potassium and sodium bicarbonate along with nerol (a compound found in citrus essential oil) exhibited a notable inhibitory effect on A. solani, the pathogen responsible for early potato blight.

Walker (1952) stated that this approach is an effective strategy for managing Alternaria diseases since it aids in decreasing primary inoculum. They suggested treating seeds with hot water at 50°C for 30 minutes to manage Alternaria diseases in cabbage, while Ellis (1968) advised the same temperature for 25 minutes to remove Alternaria infection from Brassicaceae seeds. The use of 0.3 percent Thiram combined with Captan (1:1) for seed treatment, along with four sprays of Zineb (0.25 percent), proved to be very effective in controlling this disease in chilies.

Katiyar *et al.* (2001) found three varieties of bottle gourd to be resistant to A: Azad Harit, 7002, and 7003; Cummerina. Two genotypes of chilli, CA 87-4 and CA 748, known for their high resistance, have been documented for their effectiveness against fruit rot caused by Alternaria.

Matharu *et al.* (2006) stated that the genotypes of tomatoes, namely. Arka Alok, Arka Abha, Arka Meghali, Arka Saurabh, IIHR-305, IIHR-308, IIHR-2266, IIHR-2285, and IIHR-2288 have shown resistance to early blight. Similarly, scientists globally are concentrating on the expression of diverse genes that code for proteins essential for eliciting resistance in various crops.

Namanda *et al.* (2004) stated that Alternaria leaf blight can be managed by minimizing extended wetness on leaf surfaces, conducting cultural scouting, ensuring proper drainage, and promoting the growth of fungicide-resistant host plants.

Babu *et al.* (2000) indicated the antagonistic characteristics of different bacteria and actinomycetes, thus promoting the use of particular agents for bio-control. Their eco-friendliness is another significant reason for their growing use. The growth of mycelial A. Solani responsible for tomato leaf blight was also inhibited by *Bacillus subtilis* and *Trichoderma viridae*.

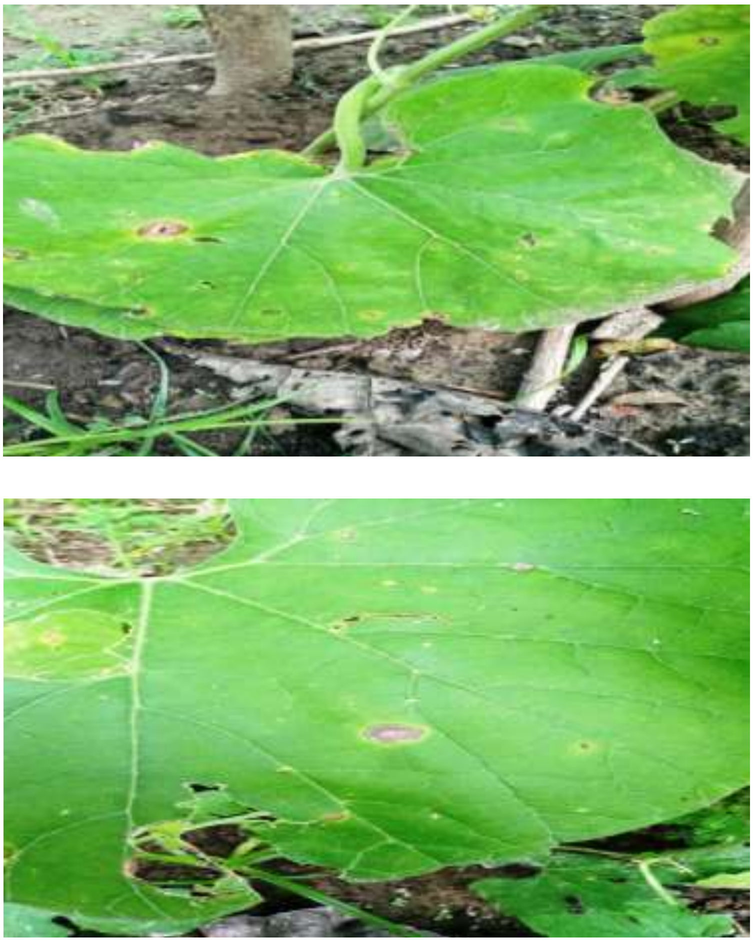

Figure 1: Symptom of *Alternaria* leaf spot on bottlegourd

Figure 2: Culture of *Alternaria cucumerina*

Figure 3: Conidia of *Alternaria cucumerina*

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THE IMPACT OF GLOBAL CLIMATE CHANGE ON OUR EARTH AND FUTURE: CAUSES, EFFECTS AND POSSIBLE SUSTAINABLE SOLUTIONS

Abstract

Climate change known as the long-term shifts in Earth's temperature and atmospheric condition. Primarily driven by natural processes and anthropogenic activities such as release of greenhouse gas in environment. The emission of greenhouse gases from fossil fuel combustion that causes the global warming and environmental pollution. The objective of this study is to analyze the causes, impacts, and potential solutions to climate change. It aims to assess the role of natural and anthropogenic factors in global warming and evaluate their effects on ecosystems, weather patterns, human health and biodiversity. Scientists widely agree that this ongoing increase in temperature has long term consequences, affecting not only climate conditions but also leading to unpredictable weather patterns, rising sea level, melting glaciers, loss of biodiversity and increased natural disasters. Additionally global warming poses serious threats to human health, increasing mortality rates and frequency of disease outbreaks. Urgent global action through sustainable practices and policies is essential to mitigate its impact.

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Climate change remains one of the most important environmental problems faced by the world today, impacting societies, ecosystems, and economies across the regions. This book chapter reviews the causes and impact of climate change while exploring potential strategies to mitigate its impact. Various approaches to reducing greenhouse gas emissions and minimizing environmental damage have been examined, offering insights into possible solutions for a more sustainable future. Collective global action is essential to safeguard the planet for future generations.

Keywords: Climate change, mitigation, mortality, anthropogenic, greenhouse gases, biodiversity, sustainable practices.

I. INTRODUCTION

Climate change defined as the long- term shifts in earth's temperature and weather conditions (UN). Climate change is the most critical problem of our era, affecting both the planet and its living organisms (Waheeb et al 2022). The main reason behind climate change is the anthropogenic activities, particularly deforestation, population growth and urbanization, desertification, agriculture, industrial processes and the excessive release of greenhouse gases (GHGs) as like carbon dioxide, methane, nitrous oxide, CFCs, water vapour and other. Climate change affect either from natural environmental factors such as volcanic eruption, solar cycle variation, slow changes in the earth's orbit around the sun (Muhammad Nda et al.,2018). The global climate is continuously changing, including increasing temperature, rising sea level, melting polar ice caps, changing the pattern of precipitation in different geographical areas and increasing harsh weather events as like floods, droughts, heat waves etc. these changes harshly impact various aspects of life, including natural habitats, human health, agriculture, and water resources. Climate change can lead to various possible impacts on the environment, society and economy (InduNasheir et al., 2020). The changes that occur due to the Earth’s changing climate threaten life because life requires favourable conditions for existence. The saddest reality of this change is that many species will disappear before being discovered.

The climate change is a real threat and fact of our life, and it is not the concern of just one nation; it is a global issue.The world is interconnected, so it is every nation’s responsibility to create sustainable solutions to tackle climate change because Earth is the only known planet in the universe where life exists with such a vast diversity. However, Earth is gradually becoming uninhabitable for a large number of species, as seen in the sharp decline in floral and faunal diversity. Even a small increase in global climate temperature leads to extreme weather events. The Intergovernmental Panel on Climate Change (IPCC) estimates that the ongoing rate of greenhouse emissions could result in a temperature increase of approximately 0.2 degree Celsius per decade, potentially surpassing the critical 2-degree Celsius threshold above pre – industrial levels by 2050 (UlufemiAdedeji et al.,2014).

Under the Paris Agreement, nations committed to reducing greenhouse gas emissions to limit global warming to well below 2 degree Celsius, with an aspirational target of 1.5 degree Celsius. If not now, then when? There is no corner of the Earth untouched by the impact of climate change. Scientific evidence strongly indicates that urgent action is necessary to minimize global warming and prevent its most severe consequences, ensuring a habitable planet for future generations (IPCC).

World Meteorological Organization Chief PetteriTaalas has said, 'There is hope' to reverse the worrying concentration rates, but the time to act is now. 'Without rapid cuts in CO_2 and other greenhouse gases, we will be heading for a upside increase of temperature by the end of this century,' he stated (Manish Kumar Yadav et al., 2017).

The reality of climate change is undeniable, and its consequences are already being felt worldwide. The time to act is now—through collective responsibility, innovation, and sustainable choices, we can protect our planet for future generations.The aim of this review study is to provide a comprehensive analysis of climate change by focusing on its key causes and highlighting its social, environmental, and economic impacts. Moreover, it aims to emphasize the pressing need to embrace mitigation and adaptation methods, such as reducing greenhouse gas emissions, reforestation, transitioning to renewable energy, enhancing climate-resilient infrastructure, and mindful consumption of natural resources.

II. UNDERSTANDING WEATHER, GLOBAL WARMING AND CLIMATE CHANGE

It is crucial to understand the differences between these terms. Weather describes the condition of the atmosphere at a particular time and place, including elements such as temperature, humidity, cloud cover, precipitation, and wind. Certain weather phenomena, like thunderstorms, tornadoes, and monsoons, occur in specific regions during particular seasons.

The terms "climate change" and "global warming" are often used as synonyms, but they have different meanings. Global warming can be defined as, increase in Earth'ssurface temperature due to the buildup of greenhouse gases, primarily caused by anthropogenic activities as like burning fossil fuels and deforestation. In contrast, climate change encompasses broader, long-term shifts in global weather patterns, including variations in temperature, rainfall, wind, and other atmospheric elements. Therefore, when discussing factors beyond just rising temperatures, the term "climate change" is more appropriate.

Causes of Climate Change

Climate change is one of the major risks to life on Earth (Pragya Nema et al., 2012). The biggest threat to humanity today is climate change, driven by various factors, primarily greenhouse gas emissions. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), and others. CO_2 is the major component of greenhouse gases, contributing approximately 75% of global emissions, primarily due to the burning of fossil fuels (MohdShalahauddin Adnan et al., 2018). Since the 19th century, anthropogenic activities have become the main driver of global climate change. According to a report by the Intergovernmental Panel on Climate Change (IPCC), there is a very high probability (more than 95%) that human actions have significantly play a crucial role to the rise in globaltemperature over the last five decades.

The major cause responsible for climate change is the burning of uncontrolled fossil fuels, including coal, oil, and natural gas, which releases greenhouse gases into the atmosphere. These gases form a layer around Earth, trapping heat from the sun and leading to an increase in global temperature. The IPCC reports that industrial processes have increased atmospheric CO_2 levels from 280 ppm to 400 ppm over the past 50 years. The unsustainable consumption patterns of wealthy, industrialized nations are major contributing factors. The rapid movement of goods leads to the release of CO_2, nitrous oxide, sulphur dioxide, and non-methane hydrocarbons. While human activities are the primary cause of climate change, there are also some natural contributors to global climate change.

Natural Causes of Climate Change

Certain environmental factors contributing to climate change include volcanic eruptions and variations in solar radiation, both of which affect global temperatures. Volcanic eruptions can inject aerosols into the atmosphere, temporarily cooling the planet by reflecting sunlight. Fluctuations in solar radiation, associated with sunspot activity, may also impact global temperatures. Another natural factor influencing global climate is the El Niño–Southern Oscillation (ENSO), a climate pattern involving ocean-atmosphere interactions in the tropical Pacific. During El Niño events, warmer waters accumulate along the South American coast, altering weather patterns worldwide every 3 to 10 years. This typically leads to wetter conditions in South America, while North America experiences milder but stormier winters. Additionally, the Atlantic Ocean tends to see fewer or weaker storms due to increased wind shear in the Caribbean. La Niña, the opposite phase of ENSO, involves stronger trade winds pushing warm water toward Asia, increasing upwelling along the Americas. This results in colder, nutrient-rich waters that support more marine life. La Niña shifts the jet stream northward, bringing drought to the southern United States, heavy rains to the Pacific Northwest, and colder northern winters. It can also intensify hurricane seasons.

Human Contributions to Climate Change

Anthropogenic activities, including burning fossil fuels, deforestation, industrialization, agricultural practices, population growth, urbanization, and the unsustainable consumption of natural resources, have significantly increased greenhouse gas emissions. Fossil fuel combustion releases large amounts of CO_2, CH_4, and other greenhouse gases (GHGs), which drive global climate change. Approximately 80% of global energy consumption still comes from fossil fuels like coal, oil, and natural gas, making the shift to renewable energy sources challenging.

Since the Industrial Revolution, greenhouse gas emissions have surged. The transportation using vehicle, sector is the leading contributor to CO_2 emissions, followed by the energy sector, which includes electricity generation. Another key factor is deforestation, which reduces the Earth's ability to absorb CO_2, leading to increased greenhouse gas levels. Landfills and waste disposal release methane, further intensifying climate change. Rapid urbanization and overconsumption increase energy demand and emissions. These human-induced factors have led to rising global temperatures, extreme weather conditions, and ecosystem disruptions, making mitigation efforts crucial.

Effects of Climate Change: No country on this planet is untouched by the effect of climate change. It affects both the environment and human societies, with its effects already visible today. Key impacts include rising temperatures, extreme weather events, increasing sea levels, ocean acidification, disruption to water supplies, health risks, threats to agriculture and food security, and biodiversity loss.

RisingTemperature: Increasing greenhouse gas emissions in environment that trap more heat in the Earth's biosphere, leading to a global temperature rise. NASA reports that since the Industrial Revolution, temperatures have risen by about 1°C, with projections indicating an increase of up to 4°C by the end of the century.

Sea Level Rise: Global warming accelerates the melting of ice sheets in Greenland and Antarctica, contributing to rising sea levels. NASA estimates that over 125 billion tons of ice melt annually, endangering coastal and low-lying regions. If current trends continue, sea levels could rise by as much as six feet this century, increasing risks of flooding, erosion, and saltwater intrusion.

Impact on Agriculture: Climate change poses a serious threat to global food and nutritional security. Rising greenhouse gas emissions are driving temperature increases due to the greenhouse effect. The Earth's average temperature continues to increase and is projected to increase by 2°C by the year 2100 (Gurdeep Singh Malhi et al., 2021). This warming trend is expected to result in significant economic losses worldwide. Crops and plants have specific tolerance limits, beyond which their growth and productivity are adversely affected. As a result, agricultural yields in Africa could decrease by over 30% by 2050 (MeleseGeneteMuluneh, 2021).

Extreme Weather Conditions: Harsh weather conditions are occurring more frequently. Sea levels are rising, floods and droughts are becoming more severe, storms are intensifying, and many species are facing extinction. By 2050, these impacts are expected to intensify further, leading to more heatwaves, wildfires, and floods in coastal regions worldwide. In developing countries, climate change may further strain environmental and socioeconomic systems already under pressure due to rapid urbanization, industrialization, and economic growth. Rising temperatures increase evaporation, leading to heavier rainfall and frequent flooding, while prolonged dry conditions contribute to severe drought and forest fires. Warmer oceans fuel stronger cyclones and hurricanes, causing widespread destruction, especially in coastal areas

Impact on Human Health: Climatic changing scenario has both direct and indirect consequences on human health. Rising temperatures contribute to an increase in heat-related problems as like heat waves and deaths. Changing climate conditions create a favourable environment condition for increased fertilization rate of disease-carrying vectors such as for example mosquitoes, leading to the spread of diseases like malaria, dengue, yellow fever, and viral encephalitis. Increasing temperatures also bring more extreme weather events. Floods, storms, and droughts may lead to higher injury and death rates. Additionally, psychological disorders, such as anxiety and post-traumatic stress, can occur due to climate-related disasters.

Impact on Marine Ecosystems: Global climate change has a critical impact on marine ecology. The oceans play a significant role in absorbing CO_2; however, as CO_2 concentrations rise, the oceans become more acidic, leading to ocean acidification, which negatively affects marine life. Additionally, increasing ocean temperatures reduce the ocean’s ability to absorb excess CO_2, further contributing to environmental imbalances. Decline of dissolved oxygen concentration in the ocean may also threaten marine biodiversity, disrupting food chains and ecosystem stability.

More Intense Forest Fires: Hotter and drier conditions are intensifying wildfire seasons, causing fires to spread more rapidly and burn for longer durations, endangering millions of lives and homes. In the western United States, the frequency of large wildfires doubled between 1984 and 2015. In California alone, the annual area burned by wildfires increased by 500% between 1972 and 2018. "It is clear from the devastation caused by the current wildfires in LA that rapid changes in precipitation and evaporation volatility can

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have a large impact," said Professor Sir Brian Hoskins, Chair of the Grantham Institute for Climate Change at Imperial College London.

Possible Sustainable Solutions: Between 1970 and 2004, global greenhouse gas emissions increased by approximately 70%, primarily due to heightened energy consumption. During this period, carbon dioxide (CO_2) emissions rose by about 80%, stemming from sources such as power stations, industrial facilities, vehicles, residential buildings, and offices. Notably, developed nations have historically contributed significantly to these emissions.

Population Control: Various organizations advocate for population control as a strategy to combat global climate change. Their approaches include ensuring access to family planning, reproductive healthcare, and information; simplifying complex political barriers; and raising public awareness about population growth.

Reduction of Our Reliance on Fossil Fuels: The most crucial step in tackling climate change is significantly reducing our dependence on fossil fuels. The utilization of coal, oil, and natural gas resources for industries, buildings, and transportation accounts for over 75 Percent of global greenhouse gas emissions, according to the United Nations. Beyond driving climate change, these energy sources also pose severe risks to both ecosystemsand human health. Transitioning to renewable and energy-efficient alternatives is essential.

Transportation: The transportation sector is one of the fastest-growing contributors to carbon dioxide (CO_2) emissions from various vehicles, with an annual increase of 2.5%, and 7.5% in Asia, where car ownership is rapidly increasing. To reduce vehicle CO_2 emissions, cities must transition from conventional designs to robust urban mass transit schemes, such as metros, trams, and underground trains. Other effective strategies include walking or cycling for short distances instead of using vehicles, carpooling, and utilizing more fuel-efficient vehicles. Modern energy-efficient technologies, such as plug-in hybrid electric vehicles (PHEVs), along with the development of innovations like hydrogen fuel cell vehicles, have the potential to reduce petroleum consumption and lower carbon dioxide (CO_2) emissions. Transitioning freight transportation from air and truck modes to electric rail systems can also lead to significant emission reductions.

Carbon Management: Carbon management encompasses strategies aimed at reduction of greenhouse gas release, particularly carbon dioxide (CO_2), to mitigate climate change. A key component of these strategies is Carbon Capture and Storage (CCS), which involves capturing CO_2 emissions from sources like power plants and industrial processes, transporting the captured CO_2, and storing it underground in geological formations to prevent its release into the atmosphere. Despite its potential, the adoption of CCS has been limited and geographically constrained. However, technological advancements have led to more efficient carbon capture methods, enhancing efforts to reduce global warming while still utilizing fossil fuels in a more environmentally friendly manner.Government support is crucial for advancing carbon management research and implementing uniform technologies to reduce emissions. Many nations have introduced economic instruments like carbon taxes to incentivize emission reductions. A carbon tax sets a price that emitters must pay for each ton of greenhouse gas emissions, encouraging businesses and consumers to adopt cleaner practices.

Public Awareness and Education: Public awareness plays a significant contribution in promoting climate change mitigation. Raising awareness is key factor for achieving global cooperation in climate action. As climate change gains recognition as a major global issue, collaborative efforts have increased to address its impacts.

Climate change activism involves NGOs, civil society organizations, and individuals pushing for policies and practices that help mitigate its effects. Organizations such as Greenpeace, the Environmental Défense Fund, and the Sierra Club are at the forefront of promoting climate awareness and sustainable agricultural practices, as highlighted by Kuyper and Bäckstrand (Gibson OwhoroOfremu et al ., 2024).

The United Nations Climate Change Learning Partnership (UNCC) also plays a significant role in climate education. It promotes awareness through printed media and encourages environmentally friendly actions such as recycling and green transportation. Additionally, the UNCC provides online databases, awareness and training to help all individuals and businesses understand the importance of reducing carbon emission.

Afforestation and Reforestation: Forests act as carbon sinks, absorbing atmospheric CO_2. Bastin et al. (2019) estimate that global tree restoration has the potential to capture 205 gigatons of carbon, significantly mitigating climate change. Moreover, the United Nations Environment Programme (UNEP, 2021) supports large-scale afforestation projects, such as the Bonn Challenge, which aims to restore 350 million hectares of forest by 2030.

Sustainable Agriculture and Food Systems: Agriculture contributes to climate change through deforestation, methane emissions, and soil degradation. Smith et al. (2019) propose agroforestry, organic farming, and precision agriculture as sustainable alternatives. Additionally, the Food and Agriculture Organization (FAO, 2020) suggests that dietary shifts towards plant-based diets can lower agricultural emissions by 30%.

Waste Management and Circular Economy: Effective waste management plays a critical role in reducing emissions from landfills and industrial waste. Ellen MacArthur Foundation (2021) promotes acircular economy approach, emphasizing recycling, reusing, and reducing waste. Studies by Zhang et al. (2018) indicate that composting and bioenergy recovery from waste can lower methane emissions by 50%.

Technological Innovations: Emerging technologies, including artificial intelligence for climate modeling (Rolnick et al., 2019) and bioengineering for carbon-neutral materials, present additional avenues for mitigation. Innovations in energy efficiency and smart grid technologies enhance the viability of sustainable solutions.

Governmental Policies: Government policies and international agreements, such as the Paris Agreement (UNFCCC, 2015), are crucial for large-scale climate action. Carbon pricing, emission trading schemes, and subsidies for green technologies are among the most effective policy tools (Stern, 2006). The European Union's Green Deal is a recent example of policy-driven sustainability initiatives.

Collective Efforts of Organizations and Individuals

National and international organizations play a vital role in tackling climate change. Institutions such as the United Nations Environment Programme (UNEP), World Wildlife Fund (WWF), and the Intergovernmental Panel on Climate Change (IPCC) drive policy recommendations and funding for sustainability initiatives. Non-governmentalorganizations (NGOs) and grassroots movements advocate for climate justice, influencing policy and corporate responsibility.

Corporate sustainability initiatives, such as carbon neutrality pledges by multinational companies, further aid in emission reductions. Additionally, individuals contribute by adopting eco-friendly lifestyles, reducing waste, supporting renewable energy, and advocating for environmental policies. Education and community-driven initiatives have shown a significant impact in promoting climate awareness and local sustainability efforts.

III. CONCLUSION

Climate change, affected by rising greenhouse gas emissions, is one of the most important global challenges. The increasing dependence on fossil fuels for energy, transportation, and manufacturing has accelerated global warming, leading to severe environmental and social consequences. While natural factors such as volcanic activity and solar variations play a role, human-induced emissions are the primary cause of the rapid temperature rise. If left unchecked, climate change will continue to cause rising sea levels, extreme weather events, and disruptions to ecosystems and livelihoods.

To mitigate these effects, a global shift towards renewable energy sources, sustainable transportation, and energy-efficient practices is essential. Immediate action is required at both institutional and individual levels to reduce carbon emissions and promote innovative solutions. Strategies such as adopting electric and biofuel-powered vehicles, increasing reforestation efforts, and enhancing energy efficiency can significantly contribute to slowing climate change. Investing in renewable energy and carbon sequestration technologies offers a promising path to reducing greenhouse gas emissions while ensuring sustainable economic growth.

Addressing climate change requires urgent and coordinated efforts. If proactive measures are implemented effectively, the worst impacts can be prevented, securing a healthier and more stable environment for future generations.

Addressing climate change requires urgent and coordinated efforts. If proactive measures are implemented effectively, the worst impacts can be prevented, securing a healthier and more stable environment for future generations.

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IMPACT OF PESTICIDES ON HUMAN HEALTH: THE HUMAN COST OF AGRICULTURAL CHEMICALS

Abstract

Pesticides are products used to control, repel, or destroy undesirable pests such as insects, rodents, fungi, and weeds. While they contribute to improved crop production and disease control, they are also harmful to the ecosystem and public health. Over time, these substances have become integrated into our land, water, atmosphere, and food, potentially affecting human well-being—ranging from acute poisoning to chronic illnesses.

Acute toxicity from pesticides results from high or very high exposure, whereas prolonged or repeated exposure can lead to long-term health effects such as damage to the nervous system, genetic mutations, cancer, birth defects, and hormonal disruption. Not only are the active ingredients in pesticides toxic, but other substances in their formulations may further enhance or alter this toxicity.

Now more than ever, it is crucial to address these safety concerns. It is important to assess how effectively current laws and regulations protect human health and the environment. This updated discussion (Ahmad et al., 2024) explores the public health impacts of pesticides, emerging safety

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issues, and legal measures. Therefore, stronger education, training, and regulatory enforcement are needed to limit the adverse effects of pesticides, encourage safer usage, and promote healthier agricultural practices.

Keywords: Pesticides, Acute toxicity, Integrated Pest Management, Alzheimer's disease, Parkinson's disease,

I. INTRODUCTION

Pesticides are chemical substances used to inhibit, control, or destroy pests—such as weeds, insects, and other organisms—that negatively affect plant growth. These substances are categorized based on their chemical structure, mode of action, toxicity levels, and method of application (Khan et al., 2023; Ahamad et al.; Kumar et al., 2023). Global demand for pesticides has increased significantly since the mid-20th century, particularly from the 1940s onward, due to the rise of commercial agriculture (Elbialy et al., 2021; Trellu et al., 2021; Singh et al., 2020; Umapathi et al., 2022).

Pesticides have often been applied excessively and without adequate regulation to food and soil, contributing to widespread environmental pollution from agricultural and aquatic sources (Cech et al., 2023). Residues frequently remain on fruits, vegetables, processed foods, as well as in water, air, and soil—posing a significant public health risk, especially in developing countries where exposure levels are higher.

Pesticides can severely impact human health because many are carcinogenic (cancer-causing), cytotoxic (damaging to cells), and mutagenic (causing genetic mutations) (Fang et al., 2020). Additionally, since most pesticides are not species-specific, they often harm non-target organisms, including humans. According to a joint report by the World Health Organization (WHO) and the United Nations Environment Programme (UNEP), approximately three million people are poisoned by pesticides each year, with around 200,000 deaths occurring in developing countries (Boedeker et al., 2020).

Pesticide exposure is also linked to biological effects such as the generation of reactive oxygen species (ROS), which deplete antioxidant reserves. This weakens the body's ability to counteract oxidative stress, disrupting the biochemical functions of essential biomolecules like proteins, fats, and nucleic acids. These disruptions can interfere with vital biological processes and contribute to acute or chronic health conditions (Kaur et al., 2019).

Moreover, pesticide application poses additional health risks, contributing to acute poisoning and chronic diseases, including various cancers (e.g., brain, breast, prostate, bladder, and colon) (Rani et al., 2021; Singh et al., 2018), Alzheimer's disease (Frisoni et al., 2022), Parkinson's disease (Perrin et al., 2021), neurotoxicity (Sanborn et al., 2007; Wang et al., 2024), infertility (Bhardwaj et al., 2018; Foucault et al., 2021), leukemia (Rafeeinia et al., 2022), and diabetes (Hernandez-Mariano et al., 2022), many of which are not yet fully understood.

Despite these risks, pesticides remain essential in agriculture, as they help increase crop yields by reducing damage from pests, weeds, and diseases (Popp et al., 2013; Tudi et al., 2021). They also play a key role in maintaining nutritional security by ensuring both the quality and quantity of food production.

As valuable public health tools, pesticides are used to control disease vectors—such as mosquitoes, ticks, and fleas—that spread illnesses like malaria, dengue fever, and Lyme disease (Tudi et al., 2021; Kitchen et al., 2009).

Recent advancement in pesticide technologies is aim to reduce environmental and health impacts. These developments have resulted in more eco-friendly formulations, including powders, solutions, and emulsifiable concentrates (Hazra et al., 2017; Zuma et al., 2023). However, achieving a balance between agricultural productivity and human and environmental health remains critical. Long-term, effective pest control with minimal adverse effects can be realized by promoting safe pesticide practices such as Integrated Pest Management (IPM) (Ahmad et al., 2024).

Alzheimer's Disease: The Hidden Danger of Pesticide Exposure

Alzheimer's disease (AD) is the most common form of cognitive decline among older adults, and the number of individuals affected by this condition is raising worldwide (Liu et al., 2023). There is compelling evidence that exposure to pesticides may increase the risk of brain disorders. Men are more frequently exposed to pesticides than women, primarily due to occupational roles (Li et al., 2014).

A study conducted in rural Cache County, a farming region in the southeastern United States, identified a strong link between certain pesticides particularly organochlorines and the development of Alzheimer’s disease and other forms of dementia (Yan et al., 2016; Hayden et al., 2010). Prolonged exposure to these chemicals has been shown to damage brain tissue and worsen Alzheimer’s symptoms (Hayden et al., 2010). A separate study reinforced these findings, identifying pesticide exposure as a significant contributing factor in the disease’s progression (Hayden et al., 2010).

Further research has identified pesticides as an additional risk factor for Alzheimer’s. One study found elevated levels of DDE, a breakdown product of the pesticide DDT, in the blood of individuals with Alzheimer’s disease (C.S.O. Health et al., 1994; Richardson et al., 2014).

Pesticide exposure during pregnancy can also affect brain development in children. Pregnant women exposed to organophosphate pesticides are more likely to give birth to children with long-term cognitive impairments (Hernandez et al., 2017; Gonzalez-Alzaga et al., 2014). Other studies have shown that exposure to organochlorine pesticides, both before and after birth, may predispose children to cognitive deficits and possible symptoms of autism, as these substances can damage brain cells responsible for memory and information processing.

Historical incidents further highlight the neurological risks of toxic chemicals. For example, long-term brain dysfunction was observed in American soldiers exposed to nerve agents (cyclosarin and sarin) during the 1991 Gulf War (Carles et al., 2017; Yan et al., 2023). A similarly tragic case involved survivors of the 1995 Tokyo sarin gas attack, many of whom suffered lasting health issues despite only brief exposure to the chemical agent.

In conclusion, substantial evidence suggests that pesticide exposure poses a significant threat to both environmental and public health, contributing to neurological disorders such as Alzheimer’s disease.

The Link between Pesticide Exposure and Parkinson's Disease

Parkinson's disease (PD), a progressive neurological disorder, is the second most common neurodegenerative disease after Alzheimer's. Growing evidence indicates that exposure to pesticides and their metabolites play a significant role in the development of PD. These substances interfere with cellular energy production and disrupt the metabolism of foreign compounds, contributing to neurodegeneration (Perrin et al., 2021; LeCouture et al., 1999; Rajawat et al., 2023).

Animal studies have provided insights into this relationship. For instance, rats exposed to rotenone, a pesticide, experienced progressive degeneration of nerve cells in the peripheral nervous system, particularly a reduction in motor nerve conduction velocity in the sciatic nerves. This deterioration is associated with dopamine deficiency and the breakdown of neurochemical synapses in the peripheral nervous system (Binienda et al., 2013).

A meta-analysis of 26 studies revealed that 15 reported a clear association between pesticide exposure and Parkinson's disease. Both cohort and case-control studies have confirmed that exposure to specific pesticides, such as mancozeb and paraquat, significantly increases the risk of developing PD (Pezzoli & Cereda, 2013; Priyadarshi et al., 2000).

Paraquat, in particular, is a potent inducer of oxidative stress, generating reactive oxygen species (ROS) a key mechanism implicated in PD. The disease itself is multifactorial, involving several biochemical pathways such as mitochondrial dysfunction, oxidative damage, endoplasmic reticulum (ER) stress, alterations in dopamine metabolism, inactivation of tyrosine hydroxylase, and reduced levels of brain-derived neurotrophic factor (BDNF). These combined factors contribute to the programmed cell death of dopaminergic neurons in the substantia nigra pars compacta, a hallmark of PD pathology (Zhang et al., 2016; Martinez-Chacon et al., 2021).

Both in vitro and in vivo studies using paraquat-based models have confirmed that paraquat exacerbates Parkinson's disease by inducing oxidative damage (Alizadeh et al., 2022). Epidemiological data also support these findings - long-term exposure to paraquat has been consistently associated with a higher likelihood of developing Parkinson's disease (See et al., 2022).

Pesticide Exposure and Breast Cancer Risk

Pesticide exposure is a significant public health concern due to its potential link to cancer development. Research has shown a connection between pesticide use and an increased risk of breast cancer (Rani et al., 2021). Similar to other carcinogenic mechanisms such as DNA damage and estrogen receptor disruption pesticides may alter breast tissue and increase cancer susceptibility, especially through genetic mutations in vulnerable individuals.

Agricultural pesticides, in particular, are believed to impair reproductive health by disrupting the endocrine system**,** contributing to cancers such as breast and colon cancer (Rebouillat et al., 2021; Sasikala et al., 2023; Ferro et al., 2012). For example, chlorpyrifos (CPF) has been shown to disrupt antioxidant balance in breast cancer cells (Ventura et al., 2015). Certain organochlorine compounds (OCs) are suspected to be carcinogenic due to their ability to mimic estrogens in breast tissue.

Studies have found that widely used pesticides including DDT, heptachlor epoxide, chlordane, and heptachlor are present in breast milk samples. Women with higher blood concentrations of DDE, a metabolite of DDT, had an elevated risk of breast cancer compared to those with lower levels (Rivero et al., 2015; Wolff et al., 1993).

A study conducted in Oakland, California, found that elevated blood levels of p,p’**-**DDT were associated with an increased risk of breast cancer in women exposed to the chemical before the age of 14 (Cohen et al., 2007). Similarly, research from Tunisia reported that high blood concentrations of organochlorine pesticides were correlated with a greater risk of breast cancer (Arrebola et al., 2015).

Poisoned Minds: Can Pesticides Trigger Brain Cancer?

The mechanisms by which pesticides may contribute to the development of brain tumors are not fully understood. However, some pesticides have been shown to cause DNA damage**,** a primary driver of cancer cell formation (Kapeleka et al., 2021). Additionally, pesticides can interfere with the body's hormonal balance, which may promote the growth of certain cancers (Ejaz et al., 2004).

A study by Greenop et al. (2013) found a correlation between pesticide exposure before and during pregnancy and an increased risk of brain tumors in infants. The authors concluded that both parents should avoid pesticide exposure during this critical developmental period. Other research also links domestic pesticide use to childhood brain tumors**,** including gliomas, resulting from indoor exposure.

Furthermore, a link has been identified between occupational pesticide exposure in parents and an increased incidence of brain cancer in their children (Maele-Fabry et al., 2017). Research also continues to explore the association between pesticide exposure and other types of brain tumors, such as meningiomas (Yousefi et al., 2022; Navas-Acien et al., 2002).

However, despite these findings, the current body of evidence remains inconclusive and sometimes inconsistent. More research is needed to clarify the exact role of pesticide exposure in the development of brain cancer and to confirm whether a definitive causal link exists.

Prolonged Pesticide Exposure and Liver Cancer

Prolonged exposure to carcinogenic pesticides has been linked to an elevated risk of liver cancer (Barsouk et al., 2021). Recent studies have begun exploring the association between pesticide exposure and hepatic cancer (Zhang et al., 2022). While some pesticides—particularly certain herbicides and fungicides—have been implicated, the exact mechanisms through which they contribute to liver cancer are still not fully understood (Zhang et al., 2022).

Many of these pesticides have been shown to cause DNA damage, leading to the malignant transformation of liver cells. Biological pathways commonly associated with pesticide-induced cancer include oxidative stress, inflammation, and endocrine disruption (Ejaz et al., 2004; Haque et al., 2022; Mnif et al., 2011; Yang et al., 2019). Specifically, organochlorine pesticides are strongly associated with liver carcinogenesis (Engel et al., 2019).

Due to their persistence in the environment, these chemicals can bioaccumulate in human tissues over time, contributing to cancer risk—especially when combined with other environmental or genetic risk factors. Occupational exposure has also been highlighted as a contributing risk for liver cancer, particularly among those who handle or apply pesticides (Saad-Hussein et al., 2019). Agricultural workers, for example, are considered a high-risk group due to prolonged and repeated exposure (Damalas & Koutroubas, 2016). Although the evidence suggests a relationship, a definitive causal link between pesticide exposure and liver cancer has yet to be fully established.

Cognitive Impairment Linked to Pesticide Exposure

There is growing evidence linking pesticide exposure **to** neurological disorders and behavioral problems, though long-term studies on chronic exposure are limited (Sasaki et al., 2023). In the Prospective Investigation of the Vasculature in Uppsala Seniors (PIVUS), blood samples from 989 individuals aged 70 were analyzed for three organochlorine (OC) pesticides: trans-nonachlor, hexachlorobenzene, and p,p′-DDE. Participants with higher concentrations of OC pesticides were found to be three times more likely to experience cognitive decline than those with lower levels (Lee et al., 2016).

Similarly, a study of 929 vineyard workers in France (aged 42–57) found that pesticide exposure significantly increased the odds of failing cognitive function tests, with odds ratios ranging from 1.35 to 5.60 (Baldi et al., 2011).

Three separate studies on prenatal exposure to organophosphate (OP) pesticides consistently reported lower IQ scores, reduced perceptual reasoning, and poorer memory in exposed children (Bouchard et al., 2011; Engel et al., 2011; Rauh et al., 2011). These findings suggest a profound neurodevelopmental impact of early-life pesticide exposure.

Silent Struggle: How Pesticides May Be Undermining Your Fertility

Fertility**,** defined as the ability to conceive within 12 months, can be affected by both male and female reproductive health. Although some studies have reported no association between pesticide exposure and abnormal sperm characteristics, others have found links between organophosphate metabolites and sperm aneuploidies, as well as erectile dysfunction (Bhardwaj et al., 2018; F.J. Paumgarten, 2020; Greenlee et al., 2003; Recio et al., 2001; Chhillar et al., 2023; Oliva et al., 2002).The women exposed to herbicides during the two years prior to attempting conception were more likely to experience infertility (Greenlee et al., 2003; Oliva et al., 2002).

Other studies show that dietary exposure to pesticide residues may also impact fertility. In men attending fertility clinics, consumption of fruits and vegetables with high pesticide residues was associated with lower ejaculate volume, sperm count, and percentage of morphologically normal sperm (Hood et al., 2022;

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Fortes et al., 2013). Even produce with low to moderate pesticide residue levels has been linked to adverse effects on sperm morphology. These findings suggest that dietary intake of pesticide-contaminated foods may significantly impair spermatogenesis (Chiu et al., 2015).

Pesticide Exposure and Leukemia

Leukemia, a cancer of the blood-forming tissues, has been increasingly associated with pesticide exposure. This form of cancer involves the overproduction of abnormal white blood cells, weakening the body's immune system. Studies have shown that individuals with frequent and prolonged pesticide exposure—especially agricultural workers, farmers, and pesticide applicators are more likely to develop leukemia (Rafeeinia et al., 2023; A. Nguyen, 2023).

Twelve pediatric case-control studies on pesticide exposure and childhood leukemia reported significantly increased risks: odds ratios were 1.39 for preconceptional exposure, 1.43 for in utero exposure, and 1.36 for postnatal exposure. Children whose parents were occupationally exposed to pesticides were three times more likely to develop leukemia. A specific study in Iran found that farmers had a higher risk for acute leukemia, and this risk was also observed in their children (Maryam et al., 2015).

The Children's Cancer Study Group has identified parental pesticide exposure as a key risk factor for acute lymphoblastic leukemia (ALL). Moreover, children exposed to household pesticides more than three times per year were found to be 3.5 times more likely to develop leukemia (Mott, 1997). Alarmingly, infants exposed to pesticides during pregnancy—particularly those under one year of age—face a sevenfold higher risk of leukemia after exposure to permethrin (Singh et al., 2018).

From Fields to Flare-Ups: How Pesticide Exposure Sparks Allergic Reactions

When an individual is first exposed to pesticides, the body attempts to eliminate these foreign substances. However, repeated exposure can lead to allergic sensitization, a process in which the immune system begins identifying these chemicals as allergens. This can result in allergic reactions such as anaphylaxis, asthma, skin rashes, hives, eye irritation, and respiratory discomfort (Owens et al., 2010; Y. Juntarawijit & C. Juntarawijit, 2023).

Exposure to phthalates, which are found in some pesticides, has also been associated with respiratory issues like asthma (North et al., 2014; Kimber & Dearman, 2010). Studies have shown that children exposed to phthalates in household environments are more likely to develop allergic symptoms. A nationwide U.S. survey also found a link between high-molecular-weight phthalates and increased allergic reactions among adults (Odebeatu et al., 2019; Hoppin et al., 2013).

Furthermore, heating PVC materials can release vapors that cause asthma in adults. Experimental research has shown that some phthalates act as immune system stimulants in animal models, amplifying allergic responses (North et al., 2014; Kimber & Dearman, 2010; Jaakkola & Knight, 2008). Another chemical, p-phenylenediamine (p-PDA), a known allergen, has been associated with skin sensitization, rhinitis, and work-related asthma (Baur & Bakehe, 2014; Helaskoski et al., 2014; Malvestio et al., 2011).

Pesticide Regulation and Control

Global pesticide regulations have been thoroughly reviewed by Handford et al. (2015), who identified significant disparities between countries and regions. There is a clear tendency for nations with advanced industrialized economies to enforce more stringent pesticide regulations, while developing countries often face challenges in implementing effective legislative measures due to financial and technical limitations.

Notably, the European Union is recognized for having one of the most rigorous pesticide regulatory frameworks in the world (Handford et al., 2015). A comprehensive reassessment carried out between 1998 and 2009 in the EU resulted in the prohibition of approximately three-quarters of the active pesticide ingredients that were previously approved.

Maximum Residue Limits (MRLs) represent the highest permissible levels of pesticide residues when these substances are used according to good agricultural practices. Most countries set MRLs to regulate pesticide levels in food and feed; however, there are notable discrepancies in MRL values across different nations (Handford et al., 2015). For instance, a comparison of the EU, Canada, the United States, China, India, Japan, South Africa, and Australia revealed that the EU enforces the strictest MRLs, while the United States permits the highest residue levels. In contrast, developing countries struggle to enforce regulations related to the use, storage, labeling, disposal, and transportation of pesticides.

Future Prospects

The use of pesticides presents a range of risks, including environmental degradation, human health hazards, and the development of pest resistance (Cechet et al., 2023; Bhandari et al., 2018). To mitigate these risks, it is essential for governments, research institutions, and private sectors to prioritize the development of safer alternatives to synthetic pesticides.

One such alternative is Integrated Pest Management (IPM), an environmentally sensitive strategy that employs a combination of biological, physical, mechanical, and chemical control methods. IPM involves monitoring pest populations, accurately identifying pests, establishing action thresholds, and applying the least toxic pest control options when necessary (S. Azayan, 2019).
To support safer pesticide use, there should be comprehensive regulations governing their distribution and application. These regulations must include pre-approval testing, risk assessments, and ongoing monitoring and evaluation to ensure safety throughout the pesticide lifecycle (Martin et al., 2023).

Equally important is the provision of education and specialized training for agricultural workers, farmers, and pesticide applicators. This training should emphasize risk recognition, correct handling, proper use of personal protective equipment (PPE), safe storage practices, and compliance with product label instructions.

Given the global scope of pesticide-related challenges, International collaboration is essential to harmonize safety standards and promote sustainable pest management strategies (Rani et al., 2021; Ahmad et al., 2024).

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EFFECT OF ENVIRONMENTAL STRESS ON BIODIVERSITY OF INDIA

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Abstract

India, a megadiverse country, is home to approximately 7-8% of the world's recorded species. However, rapid environmental changes pose severe threats to its rich biodiversity. This study deals with the impact of environmental stressors—like climate change, habitat destruction, pollution, and invasive species—on India's flora and fauna.

Climate change has led to change in temperature, erratic monsoons, and intense weather events, disrupting ecosystems and altering species distribution. Habitat loss due to deforestation, urbanization, and agricultural expansion has fragmented wildlife populations, reducing genetic diversity and increasing extinction risks. Pollution, particularly air, water, and soil contamination, has adversely affected aquatic and terrestrial species. Additionally, invasive alien species, introduced through trade and human activities, outcompete native species, leading to ecosystem imbalances.

The Himalayas, Western Ghats, Sundarbans, and Thar Desert—India's biodiversity hotspots—are experiencing significant ecological stress. High-altitude species in the Himalayas face habitat shrinkage, while mangroves in the Sundarbans suffer from rising sea levels and salinity intrusion. The Western Ghats, a repository of endemic

species, are under threat from deforestation and mining activities. Desertification in the Thar region further exacerbates biodiversity loss.

To mitigate these impacts, conservation initiatives such as afforestation, wildlife corridors, and biodiversity action plans are being implemented. Government policies, including the Biodiversity Act (2002) and protected area expansions, aim to safeguard endangered species. However, stronger enforcement, community participation, and climate-adaptive conservation strategies are essential for sustaining India's ecological heritage.

Environmental stressors like climate change, pollution, destructionof habitat, and disturbing species, significantly impact biodiversity. India, being is the world's most biodiverse nations, is facing a rapid decline in its rich flora and fauna due to human-induced environmental pressures. This paper explores various environmental stressors affecting biodiversity in India, evaluates their impact on different ecosystems, and discusses possible conservation strategies to mitigate these threats.

Keywords: Environmental impact, Biodiversity conservation, Climate change, Ecosystem.

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I. INTRODUCTION

Biodiversity, the foundation of ecological balance, is under severe threat due to environmental stressors. India, one of the world's 17 megadiverse countries, harbours an extraordinary range of ecosystems, from the Himalayas to coastal regions, supporting nearly 7-8% of global biodiversity. However, rapid climate change, habitat destruction, pollution, and anthropogenic pressures have significantly altered the ecological dynamics, posing a severe risk to flora and fauna.

Environmental stress in India manifests in numerous forms, including high temperatures, heavy rain, deforestation, and increasing pollution levels. Climate change has disrupted the ecological balance of ecosystems, leads in species distribution, altered breeding cycles, and extinction risks for many endemic species. Habitat fragmentation due to urbanization and agricultural expansion further exacerbates biodiversity loss by reducing genetic diversity and limiting species interactions.

Aquatic and terrestrial ecosystems in India are equally vulnerable to environmental stress. Rivers like the Ganges and Yamuna suffer from industrial and plastic pollution, threatening aquatic biodiversity. Similarly, coral bleaching in the Indian Ocean and the depletion of mangrove forests along the coastline highlight the impact of environmental degradation. The Western Ghats and Sundarbans, home to unique and endangered species, face deforestation and climate-induced habitat loss, endangering keystone species such as tigers, elephants, and the Indian pangolin.

Understanding the relationship between environmental stress and biodiversity loss is critical for conservation efforts. This paper explores the major environmental stressors affecting India’s biodiversity, their consequences on ecosystems, and potential mitigation strategies. Speak to these challenges requires a multidisciplinary approach involving policy interventions, sustainable development practices, and community participation to ensure ecological resilience and the conservation of India's rich biodiversity for future generations.

II. ENVIRONMENTAL STRESSORS AND THEIR IMPACT ON BIODIVERSITY

1. Climate Change

Climate change is the most significant threat to global biodiversity, affecting ecosystems, species, and ecological processes. High temperatures, diffrent weather patterns, and extreme climate are disrupting habitats and altering species distributions, often beyond their ability to adapt.

The primary effect of climate change on biodiversity is habitat loss. Many species depend on specific climate conditions to survive, and as temperatures rise, their habitats may become unsuitable. For example, coral reefs are highly sensitive to ocean warming, leading to widespread coral bleaching and ecosystem collapse. Similarly, polar species such as polar bears are losing critical ice habitats due to melting glaciers.

Shifts in species distributions are another consequence of climate change. Many plants and animals are migrating toward cooler regions in search of suitable conditions. However, some species, especially those with limited mobility, may struggle to relocate, leading to population declines or extinction.

Climate change also upset ecological interactions, such as ppollination, Predator-prey relationships, and food availability. For instance, altered flowering times in plants can affect pollinators like bees, which rely on seasonal cues for survival. This disruption can cascade through the food chain, threatening entire ecosystems.

Furthermore, unusual weather events such as hurricanes, droughts, and wildfires are increasing in frequency and intensity, causing habitat destruction and species mortality. Ocean acidification, due to high carbon dioxide absorption, threatens marine life, particularly shell-forming organisms like corals and molluscs.

Conserving biodiversity during the climate change requires urgent action, including habitat protection, controlling greenhouse gas emissions, and promoting ecosystem resilience. Adaptive conservation strategies like creating wildlife corridors and protecting climate refugia, are essential to mitigate the impact of climate change and preserve biodiversity for future generations.

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Climate change has led to unpredictable weather patterns, rising temperature, and altered precipitation regimes in India. Some of the significant effects include:

- **Rising Temperatures:** Increased temperatures have forced species to migrate to higher altitudes, affecting alpine ecosystems.
- **Changes in Monsoon Patterns:** Unpredictable monsoons have impacted agriculture-dependent biodiversity, especially amphibians and freshwater ecosystems.
- **Sea Level Rise:** Coastal ecosystems such as are under threat due to rising sea levels and increased salinity.

2. Habitat Destruction

Habitat destruction is a main cause of biodiversity loss, disrupting ecosystems and threatening countless species. Deforestation, urbanization, and agriculture destroy natural habitats, forcing wildlife into smaller, fragmented areas. This reduces genetic diversity, making species more prone to disease and climate change. Many plants and animals facing extinction due to habitat loss, disrupting food chains and ecosystem services like pollination and water purification. Marine environments suffer from coral reef destruction and pollution, further endangering marine life. Protecting natural habitats through conservation efforts, sustainable development, and reforestation is crucial to preserving biodiversity and maintaining ecological balance for future generations.

Habitat loss due to deforestation, urbanization, and agricultural expansion is a leading cause of biodiversity decline.

- **Deforestation:** The expansion of agriculture and urban settlements has led to massive deforestation, especially in the Western Ghats and Northeast India.
- **Fragmentation:** Infrastructure development has fragmented habitats, leading to genetic isolation of species.
- **Wetland Destruction:** Encroachment and pollution have led to the degradation of vital wetlands like Chilika Lake and Loktak Lake.

3. Pollution

Pollution significantly threatens biodiversity by degrading habitats, reducing species populations, and disrupting ecosystems. Air pollution leads to acid rain, harming forests and aquatic life. Water pollution, caused by industrial waste and plastic, contaminates marine and freshwater ecosystems, endangering aquatic

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species. Soil pollution from pesticides and chemicals affects microorganisms, plants, and animals. Light and noise pollution disturb migration, reproduction, and communication in wildlife. Toxic pollutants accumulate in the food chain, leading to health issues and population decline. Conservation efforts, stricter regulations, and sustainable practices are essential to mitigate pollution's impact and preserve biodiversity for future generations.

Pollution from industries, agriculture, and urban areas has severely impacted biodiversity.

- **Air Pollution:** Increased air pollutants affect forest ecosystems and cause acid rain.
- **Water Pollution:** Industrial discharge and agricultural runoff contaminate rivers and lakes, affecting aquatic life.
- **Soil Degradation:** Excessive use of pesticides and fertilizers depletes soil biodiversity.

4. Invasive Species

Invasive species pose a significant threat to biodiversity by outcompeting native species for resources, disrupting ecosystems, and altering habitats. They often lack natural predators, allowing their populations to grow unchecked, leading to declines to native flora and fauna. Invasive plants can alter soil composition and water availability, while invasive animals can prey on or displace native species. These disruptions reduce ecosystem stability and resilience, threatening biodiversity at local and global levels. Human activities such as trade, travel, and climate change further facilitate the spread of invasive species, making their management a critical conservation priority.

Non-native species often outcompete indigenous flora and fauna, leading to ecosystem imbalance.

- **Examples:** The spread of Lantana camara, Eichhorniacrassipes (water hyacinth), and African catfish (Clariasgariepinus) has disrupted local biodiversity.
- **Impact:** These species alter food chains, reduce native species populations, and affect ecosystem functions.

Biodiversity Hotspots at Risk

1. The Himalayas

- **Melting Glaciers:** Impacting freshwater ecosystems and endemic species.

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- **Deforestation:** Causing habitat loss for endangered species like the Snow Leopard.

2. **Western Ghats**
   - **Agricultural Expansion:** Reducing forest cover.
   - **Infrastructure Projects:** Roads, dams, and railways causing habitat fragmentation.

3. **Sundarbans**
   - **Rising Sea Levels:** Threatening the Royal Bengal Tiger population.
   - **Cyclonic Activity:** Increasing frequency of extreme weather events.

III. CONSERVATION STRATEGIES

Biodiversity conservation strategies aim to protect and restore ecosystems, species, and genetic diversity. Key approaches include **in-situ conservation**, such as establishing protected areas, national parks, and wildlife sanctuaries, and **ex-situ conservation**, like zoos, seed banks, and botanical gardens. Sustainable resource management, habitat restoration, and community-based conservation efforts enhance long-term biodiversity protection. Legal frameworks, such as environmental laws and international treaties, help regulate human activities. Reducing habitat destruction, combating climate change, and preventing species overexploitation are crucial. Public awareness, education, and scientific research further support conservation efforts, ensuring a balanced coexistence between nature and human development.

1. **Protected Areas and Wildlife Sanctuaries**
   - Strengthening conservation programs in national parks and reserves like Jim Corbett National Park, Kaziranga National Park, and the Nilgiri Biosphere Reserve.
   - Expanding community-based conservation efforts.

2. **Legal Framework and Policies**
   - Implementing and strengthening laws like the Wildlife Protection Act (1972), Environmental Protection Act (1986), and the Biodiversity Act (2002).
   - Promoting sustainable land-use policies.

3. **Sustainable Development Initiatives**
   - Encouraging afforestation and reforestation projects.

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- Implementing eco-friendly agricultural practices.
- Reducing industrial pollution through stringent regulations.

IV. CONCLUSION

Environmental stress poses a serious threat to India’s biodiversity. Urgent conservation measures, sustainable development policies, and community involvement are essential to mitigate the impact of environmental stressors. Strengthening legal frameworks, promoting ecological restoration, and increasing awareness can help preserve India’s unique biodiversity for future generations.

India's rich biodiversity is under significant threat due to various environmental stresses, including climate change, deforestation, pollution, habitat destruction, and overexploitation of natural resources. These factors have led to habitat fragmentation, species extinction, and disruption of ecological balance, posing severe challenges to conservation efforts.

Climate change, in particular, has intensified extreme weather events, altered rainfall patterns, and increased temperatures, affecting both terrestrial and aquatic ecosystems. Pollution from industrial, agricultural, and urban activities has further degraded air, water, and soil quality, threatening species survival. Additionally, human-induced activities such as deforestation and urban expansion have led to habitat loss for several endemic and endangered species.
To mitigate these threats, India has implemented conservation initiatives such as protected areas, afforestation programs, and wildlife conservation projects. However, sustainable development, stricter environmental regulations, community participation, and increased awareness are crucial to preserving biodiversity.

In conclusion, addressing environmental stress on biodiversity requires a multi-faceted approach that balances economic growth with ecological sustainability. Conservation policies must be strengthened, and innovative solutions such as eco-friendly technologies and habitat restoration should be encouraged. Protecting India’s biodiversity is essential for ecological balance, ensuring sustainable livelihoods, and protecting the country’s natural heritage for future generations.

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This paper provides a comprehensive analysis of how environmental stressors affect biodiversity in India, highlight the need for urgent conservation efforts.

HUMAN FERTILITY: AN OVERVIEW

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Abstract

Human fertility refers to the biological ability to conceive and reproduce, affected by a complex interaction of physiological, environmental, and socioeconomic factors. In recent decades, fertility rates have declined globally, especially in industrialized nations, raising concerns about population stability and economic implications. Key biological determinants of fertility include age, ovulation, sperm quality, and reproductive health conditions. Social and economic influences such as education levels, financial stability, cultural norms, and easily access to medical facilities play a crucial role in fertility trends. Environmental factors, including exposure to pollutants, toxins, and lifestyle choices like diet, smoking, and stress further impact on reproductive health. Infertility is categorized as primary or secondary and is a growing concern worldwide. Primary infertility occurs when a couple is unable to pregnant after one year of unprotected intercourse, while secondary infertility refers to the inability to pregnancy even after having a previous successful pregnancy. Both men and women can be affected, with causes ranging from hormonal imbalances and genetic disorders to lifestyle and environmental exposures.

Keywords: Human fertility, Reproductive health, Fertility rates, Infertility, Ovulation, Sperm quality, Environmental factors, Healthcare access.

I. INTRODUCTION

Fertility is the natural capacity of a living being to establish a clinical pregnancy through an intricate biological process called "reproduction" with the assistance of the reproductive system to produce offspring, the real existence of a species. Fertility in colloquial terms refers to the ability to have offspring (Segal et al. 2019).

Addressing fertility concerns requires a multidimensional approach, including healthcare interventions, public awareness, and policy measures that support reproductive health and family planning. Understanding the interplay of biological, social, and environmental factors is essential for developing effective well-being and addressing declining fertility rates worldwide (Black et al. 2016).

II. DEMOGRAPHY

Demography is a statistical and interdisciplinary field that examines the characteristics of populations, including their size, structure, and distribution, and how they change through factors like fertility, mortality, and migration. In this regard, fertility can be the actual production of living offspring, rather than the theoretically data to physical capability to produce, which can be defined as fecundity rate. Demographers measure the fertility rate in a variety of ways.

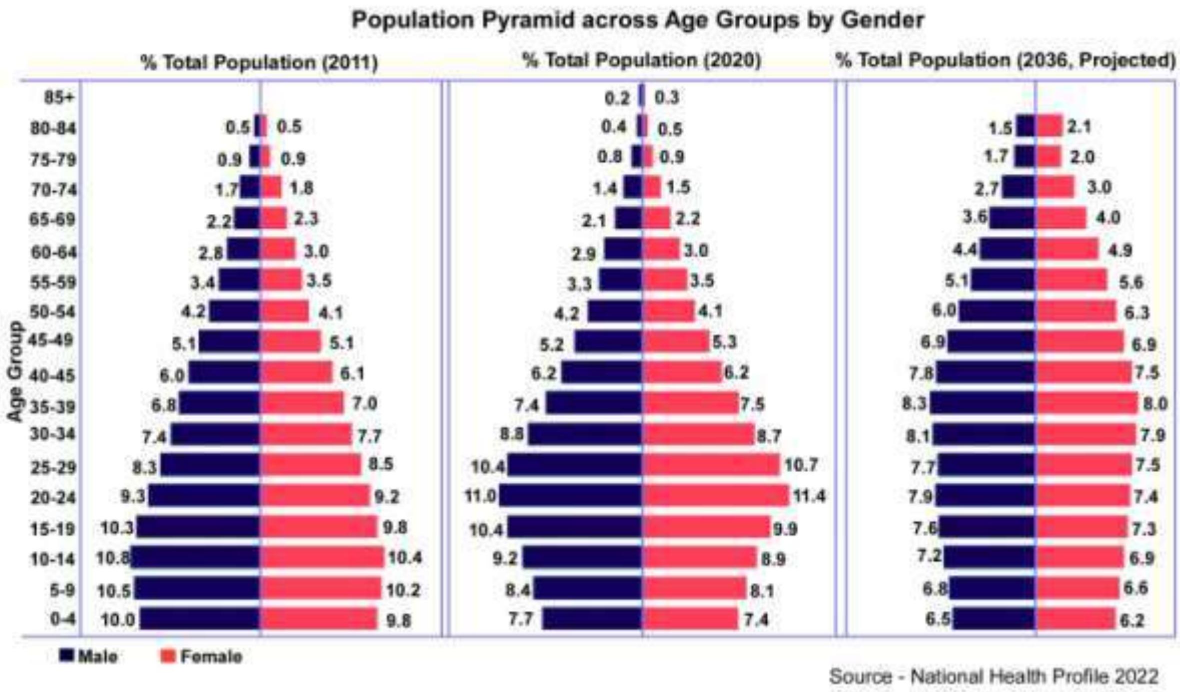


Figure 1: Graph illustrates the demographic shifts with age group population pyramid of India (Source: India Data Insights)

III. FACTOR AFFECTING FERTILITY

Fertility can be affected by a multiple environmental and biological range of factors, including age, weight, lifestyle choices (smoking, alcohol, diet), environmental factors, medical conditions, and mental health (Jurewicz, J., et al 2018).

- **For Men**

Age: Sperm quality and quantity tend to decrease with age.

Weight: Being overweight or obese can negatively affect sperm production and hormone balance.

Medical Conditions: Conditions like varicocele or infections can impact sperm production.

Lifestyle Factors

- **Smoking** reduces sperm count and motility.
- **Poor diet** leads to nutritional deficiencies affecting sperm quality.
- **Excessive alcohol consumption** lowers testosterone levels and decreases sperm health.

Environmental Factors: Exposure to different toxins and chemicals (as like pesticides, heavy metals, and photo radiation) can play a crucial role in fertility.

Mental Health: Stress, anxiety, and depression can disrupt hormone levels and reduce sperm production.

- **For Women**

Age: Fertility declines with age, especially after the mid-30s, due to decreased egg quantity and quality.

Weight: Being overweight or underweight can cause hormonal imbalances that affect ovulation (Zain et al. 2008).

Medical Conditions

- **Endometriosis:** A medical situation when tissue similar to the uterine lining grows outside the uterus, affecting fertility.
- **Polycystic Ovary Syndrome (PCOS):** Causes irregular ovulation due to hormonal imbalances.
- **Thyroid Disorders:** Can disrupt menstrual cycles and ovulation.

Lifestyle Factors

- **Smoking** damages eggs and reduces fertility.
- **Excessive alcohol consumption** can disrupt ovulation.
- **Poor diet may lead to nutrient deficiencies essential for reproductive health.**

Environmental Factors: Exposure to toxins and chemicals (such as pollutants, radiation, and industrial chemicals) can affect hormonal balance.

Mental Health: Stress, anxiety, and depression can interfere with ovulation and menstrual cycles.

Other factors like sexually transmitted infections (STIs) can cause infertility or damage to reproductive organs, and previous pregnancy history like multiple miscarriages or previous fertility treatments.

Factors Affecting Male Fertility

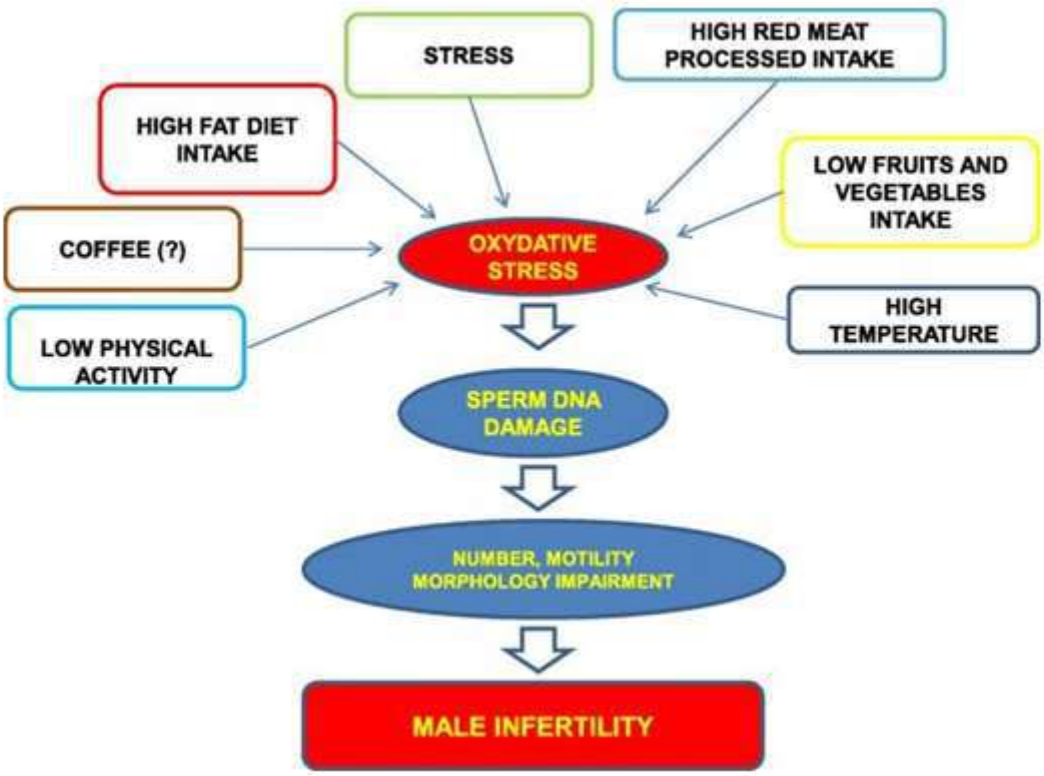


Figure 2

The factors concerned in male infertility (Alsandro et al. 2018)

Factor Affecting female infertility

Figure 3: The factors concerned in female infertility (Image Source- https://zivafertility.com/)

IV. AGE AND FERTILITY

Age significantly impacts fertility, with women's fertility declining naturally and progressively from birth, accelerating after the mid-30s, while male fertility also declines with age, albeit more subtly.

- **Male age and Fertility**
  - **Sperm Quality Decline:** In case of male, produce sperm throughout their lives, the quality and quantity of sperm can decline with age (Bray, I et al 2006).
  - **Reduced Testosterone Levels:** After 30 years, the testosterone levels decline by about 1% per year, that impacts on sperm production and libido.
  - **Longer time to Conception:** Couples where the male is over 40 may take longer to conceive compared to younger men.

- **Female age and Fertility**
  - **Nature Decline:** Women are born with a About 1-2 million eggs, but by puberty, only 300,000-400,000 remain.
  - **Hormonal Changes:** Estrogen and progesterone levels fluctuate, that affects the ovulation and menstrual cycles.
  - **Age-related Decline:** Fertility starts to decline in the late 20s or early 30s, but the decline accelerates after age 35. By age 40 the chance of getting pregnant naturally each month is significantly lower and by age 45 it's very unlikely (Brooks, A. T. 2017).

V. INFERTILITY

Infertility refers to the condition in which a couple is unable to conceive a child despite having regular, unprotected sexual intercourse for a significant period, typically one year. Infertility can result from various factors, including physical, congenital, immunological, psychological, and certain medical conditions. Some common causes include hormonal imbalances, ovulation disorders, blocked fallopian tubes, low sperm count, poor sperm motility, endometriosis, polycystic ovary syndrome (PCOS), sexually transmitted infections (STIs), thyroid disorders, diabetes, obesity, and exposure to environmental toxins. Additionally, diseases such as measles, mumps, tuberculosis, or sexually transmitted infections can contribute to infertility. The use of certain medications, recreational drugs, excessive alcohol consumption, and smoking can also negatively impact fertility in both men and women.

Table 1: Primary and Secondary Infertility in Males and Females

Aspect	Primary Infertility	Secondary Infertility
Definition	Inability to conceive after 12 months of regular unprotected intercourse, with no prior pregnancy.	Inability to conceive after previously having a pregnancy (regardless of outcome).
Male Causes	• Genetic disorders (e.g., Klinefelter syndrome) • Undescended testes • Varicocele • Low sperm count or motility • Obstruction of sperm transport	• Acquired infections (e.g., mumps orchitis, STDs) • Lifestyle factors (e.g., smoking, obesity) • Hormonal imbalance • Testicular trauma or surgery
Female Causes	• Congenital uterine anomalies • Endometriosis • Polycystic ovary syndrome (PCOS) • Primary ovarian insufficiency	• Pelvic inflammatory disease (PID) • Uterine scarring from previous pregnancy or abortion

		• Age-related decline in fertility • Adhesions from surgery
Diagnosis	Comprehensive fertility workup from the start	Fertility workup considering previous pregnancy history and new potential factors
Treatment Options	Depends on the underlying cause; may include: • Hormonal therapy • Surgery • Assisted reproductive technologies (ART)	Similar to primary, but also targets newly acquired conditions or complications from previous pregnancies
Psychological Impact	Often associated with anxiety over inability to conceive at all	Can be associated with frustration, guilt, or confusion due to previous success

The correct cause of infertility needs to be established to overcome it. The couples can be assisted to have children by a certain special technique called assisted reproductive technologies (ART), ART includes number of advanced technologies (Datta, M. 2017).

Various Assisted Reproductive Strategies (art)

In vitro fertilisation IVF or test tube babies: It is a technique in which the ovum is fertilised using a donor sperm outside the body and the fertilised ovum is implanted in the female body (uterus) for further development, it enables a woman who is not able to conceive to give birth to a normal body (Hochschild et al. 2013). Test tube babies, as the name signifies, are not reared in test tubes. Test tube fertilisation is a delicate surgery where the ova from women are removed under aseptic conditions and fertilised externally with the sperm in the laboratory. The zygote or early embryos with up to eight (8) blastomeres are transferred into the fallopian tube, called zygote intrafallopian transfer (ZIFT), or the embryos with more than eight (8) blastomeres are transferred into the uterus, called intrauterine transfer (IUT). This technique was first performed successfully with humans in Britain in 1978.

Test tube babies are born to women who had no hope of giving birth to a baby. It is a great achievement of medical science.

Gamete intrafallopian transfer (GIFT): It is another method in which an ovum is collected from a female donor and is transferred to a fallopian tube of another female who cannot produce ovum but can provide an environment for the fertilisation and further development of the foetus.

Intrauterine Insemination (IUI): In this method the semen is collected from the husband or donor is artificially introduced into either the vagina or the uterus.

In Intra Cytoplasmic Sperm Injection (ICSI): In this method, sperm is directly injected into the ovum in the laboratory, and an embryo is formed.

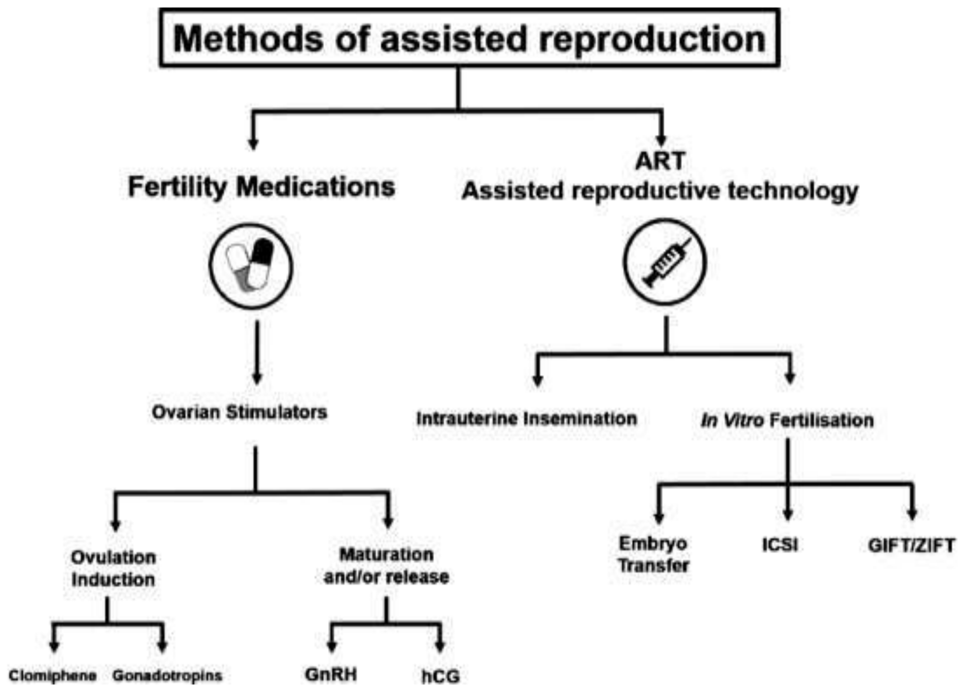
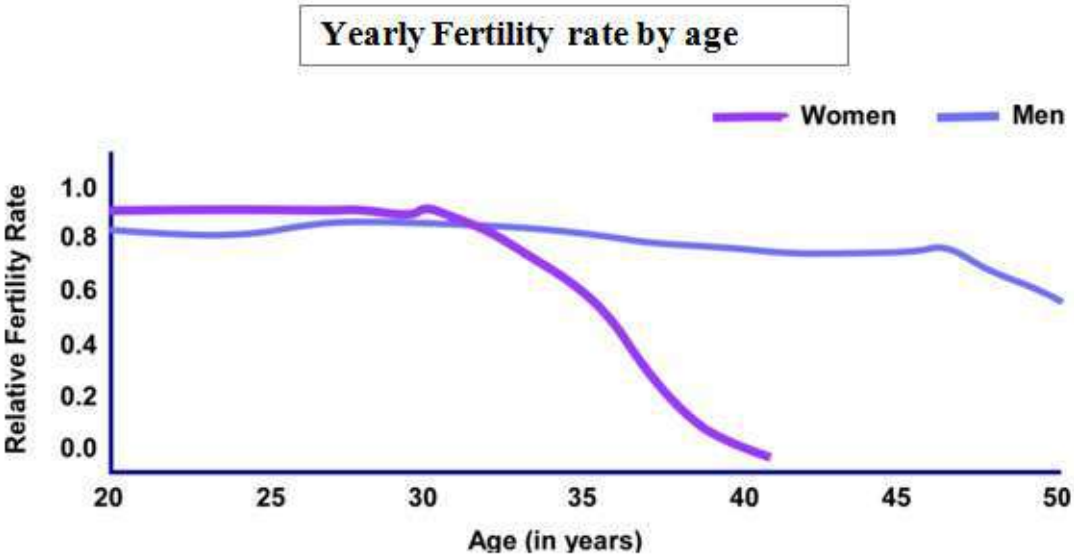


Figure 4

Overview of various assisted reproductive strategies (Gorgui and Bérard, 2018)

VI. IMPORTANT CONSIDRATION

No ‘Magic Number’, there is no single age that determines fertility, and many women in their 30s and 40s have healthy pregnancies. Assisted reproductive technologies (ART) technologies like in vitro fertilization IVF and egg donation can help women over 45 conceive (Blyth, E. 2002).



Effect of age on fecundity and outcome of pregnancy (Van Noord-Zaadstra et al. 1991)

VII. CONCLUSION

Infertility, which is a common disorder along with its treatment, puts the lady in great physiological and social stress. Special attention and care must be given individually to each lady according to her needs and risk factors, age, employment status, and duration of infertility so as to minimize the anxiety and depression levels. It is a problem health considerable social, cultural, and economic impact. It needs to be alleviated by several measures, including health education, early diagnosis, prevention and effective treatment, which include ART (Dickenson, D. L. 2013).

Infertility affects both men and women; women are liable to get pregnant or carry a foetus to full term, and a man is unable to impregnate a fertile female. Although infertility testing in women is important, it is also essential for the male partner to be tested at the same time.

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STUDYING THE EFFECTS OF DEFORESTATION ON ECOSYSTEMS AND SPECIES EXTINCTION

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Abstract

Deforestation, or the extensive clearing of forests for urban, industrial, and agricultural use, has emerged as one of the world's most urgent environmental problems. It has extensive and severe effects on ecosystems and biodiversity, setting off a chain of events that upsets ecological balance and plays a major role in the extinction of species. Forests are vital to the survival of ecological processes, including soil fertility, water cycling, and carbon sequestration, because they offer vital habitats for millions of plant and animal species. When these forests are cut down, habitat is lost, which causes ecosystems to become fragmented and species, many of which are already in danger, to become more vulnerable. Deforestation has both direct and indirect effects on ecosystems. As species lose their natural habitats, the decrease of forest cover directly contributes to biodiversity loss. Fragmentation, in which the remaining forest areas are separated from one another, exacerbates this problem by forming "islands" of biodiversity that are unable to sustain long-term healthy populations. Deforestation contributes to global warming indirectly because forests store carbon, and their loss releases large amounts of stored carbon into the atmosphere. Changes in temperature and precipitation patterns are just two examples of the additional stresses that climate change may put on ecosystems, endangering the survival of species. Because many species are unable to adapt to the quick changes in their surroundings, deforestation is contributing to an increase in the extinction rates of species. Particularly at risk are species that live in forests, such as monkeys, birds, amphibians, and insects, whose survival depends on certain habitat conditions that are frequently lost or deteriorated due to deforestation. Furthermore, species are more vulnerable to extinction because of the reduction in genetic diversity within populations brought on by habitat fragmentation, which also makes it harder for them to adapt to shifting environmental conditions.

Keywords: Environmental condition, biodiversity, soil fertility.

Deforestation, or the mass removal of trees for urban, industrial, and agricultural growth, has detrimental effects on ecosystem stability and biodiversity. There are both direct and indirect effects on ecosystems in the complicated relationship between deforestation and the extinction of species. Key findings are summarized in this review, which also offers insights into how deforestation affects species survival and biodiversity.

I. HABITAT DESTRUCTION AND DEFORESTATION

Habitats that are essential to many species' survival are directly destroyed as a result of deforestation. Deforestation mostly impacts tropical ecosystems, which are home to most of the planet's species (Foley et al., 2005). Species that are suited to particular forest conditions frequently inhabit these ecosystems. Species are forced to relocate, frequently into less suited areas, when forests are destroyed, which increases the likelihood that they will go extinct. According to Laurance (2007), deforestation frequently results in forest fragmentation, which reduces biodiversity by generating isolated habitat patches that are too small to sustain healthy populations.

II. THE ASSOCIATION BETWEEN BIODIVERSITY LOSS AND DEFORESTATION

With millions of species living there, forests are one of the planet's most biodiverse ecosystems. Deforestation results in the indirect loss of genetic diversity as well as the direct loss of species. Wilson (1988) maintained that many species with highly specific habitat requirements become extinct as a result of deforestation in tropical forests. Species that rely on forest regions for food, shelter, or breeding grounds are more vulnerable when these areas become smaller. One of the main causes of species extinction, especially for species with tiny populations and restricted ranges, is habitat loss, according to a 1995 research by Pimm et al.

III. EDGE EFFECTS AND FRAGMENTATION

Deforestation frequently causes forests to fragment into smaller pieces, which results in "edge effects," where the conditions on the edges of these fragmented habitats are different from those inside. According to Gascoigne et al. (2011), edge impacts change microclimates, causing invasive species to proliferate, temperatures to rise, and wind exposure to increase. Some species find it difficult to survive as a result of these changes because they cannot adjust to the new environment. Additionally, Laurance et al. (2002) found that competition and predation are more common in tiny, fragmented habitats, especially from non-native species that flourish in disturbed areas.

IV. DEFORESTATION AND ENDANGERED SPECIES' RISK OF EXTINCTION

Particularly at risk from deforestation are endemic species, which are found exclusively in particular regions. The loss of forests in areas where endemic species are found can cause them to go extinct very quickly. Deforestation in locations with a restricted geographic range significantly increases the danger of extinction for endemic species, as demonstrated by Brooks et al. (2002). The endemic Sumatran orangutan (Pongo abelii), for instance, is in danger of going extinct because of the fast destruction of its natural habitat in Indonesian rainforests (Meijaard et al., 2012).

V. SPECIES SURVIVAL, DEFORESTATION, AND CLIMATE CHANGE

In addition to having a direct impact on biodiversity, deforestation fuels climate change, which intensifies the consequences of habitat loss. Large volumes of carbon dioxide are released into the atmosphere when forests, especially tropical rainforests, are destroyed, hastening global warming. A vicious cycle between deforestation and climate change has been noted by Cox & McCarthy (2012). As forests are gone, the global climate becomes less stable, endangering species that are already under stress from habitat loss. For instance, animals that depend on particular climatic conditions may not survive as a result of altered rainfall patterns brought about by climate change.

VI. CONSERVATION AND RESTORATION'S FUNCTION IN REDUCING THE EFFECTS OF DEFORESTATION

Although deforestation is a serious danger to biodiversity, some of these effects can be lessened with conservation and restoration initiatives. The potential of forest restoration and reforestation as tactics to partially undo the harm brought forth by deforestation was examined by Chazdon (2008). Deforested species can find refuge and habitat connectivity through the restoration of degraded lands and the planting of native plants. But Holl & Aide (2011) warn that restoration work frequently falls short of replacing the original ecosystems' richness and complexity, particularly in regions that are highly fragmented.

VII. CASE STUDY: RAINFOREST IN THE AMAZON

The Amazon rainforest is one of the areas most severely impacted by deforestation, and it provides an important case study for comprehending how deforestation affects the extinction of species. The loss of biodiversity and the disturbance of regional and global climate patterns are two consequences of Amazonian deforestation, according to Nepstad et al. (2008). For animals like the Amazon river dolphin (Inia geoffrensis) and the jaguar (Panthera onca), habitat destruction poses a threat to their continued existence. According to Barlow et al. (2016), the Amazon's deforestation worsens the loss of species diversity and jeopardizes conservation efforts for threatened and endangered species.

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THE ROLE OF DOGS IN MENTAL HEALTH AND THERAPY FOR SOMATIC DISORDER

Abstract

Dogs can provide humans with various physical, mental and social benefits, while scientific evidence of the benefits to humans is growing. College can be a stressful time for many people, especially for those struggling with issues like stress, anxiety and depression. Research indicates that dogs can play a significant role in certain types of treatment for conditions like anxiety, stress and depression. Animal Assisted therapy is defined as targeted interaction between trained animals and their families. Therapy dog programs are delivered in various settings, including hospitals, elderly care facilities and mental health services. A recent trend on college campuses is to provide opportunities for interaction with dogs and other animals. The benefits of treatment for mentally ill people's health are related to reducing the expression of negative symptoms of the disease developing skills in various areas of patients, personalities and in addition improving their quality of life. So, that human stress can be alleviated and individuals can be helped to cope with other psychological issues. Although challenging, it is paramount to ensure that the welfare of therapy dogs is included within the Framework of One Welfare, as it is a critical factor for future sustainability. We identified various concerns due to the lack of guidelines and oversight to protect the welfare of dogs involved in these programs. In this paper,

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we discuss the current research regarding using animals for assistance in treating for human problems commonly encountered.

Keywords: Animal assisted therapy, health, mental health, sustainability

I. INTRODUCTION

Today in India, like in other countries, 40%-50% animals of the houses are keeping pets. Some of the main animals are dogs, cats, rabbits and cows etc. The traditions of keeping animals as pets are from ancient times but at present efforts are being made to connect it with science. The absence of animals helps in reducing the tension and stress of person feels comfortable. And, in this context, scientific research and given for purposes like evidence are also being therapy. Animal have been used since the 20th century, Dogs have been found to be connected to human emotions. And, now by connecting them with science many new methods related to human health are being developed where a person can interact with animal in a social way. This is having a positive effect on human health and humans can be saved from serious mental disease like somatic disorders stress, anxiety, PTSD, depression & autism. Scientists are considering dogs as an important pet to avoid suffering from these diseases and are linking them to physical health, mental health and emotional health. The presence of a dog helps to brighten the environment around a person and also helps in reducing stress. It helps to have a positive impact on the person's well-being. Therapy dog programs are delivered in a variety of settings including hospitals, aged care facilities, schools and tertiary education centers, mental health service, courts and airports. Outcomes, which have been reported by people involved in a therapy dog program, include improved socialization, mood, and decreased the symptoms of depression or anxiety. Given the remarkable range of terminology the following definition of a therapy dog will be used for this review based on Howell Nieforth "An animal who is included into the work of qualified health professional in the provision of a structured, goal directed treatment.

II. BENEFITS OF DOGS THERAPY IN SOMATIC DISORDER

Dogs play an important role in the connection between many people and help the overcome loneliness and share in their happiness. Interaction with dogs is

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used to train people to perform mental, social, physical and emotional functions in people with mental illnesses. Their involvement in the treatment of mental illness is a fact for several decades and the benefits are obtained significant. Undoubtedly any patients approach from an animal to a hospital or clinic is not included in the treatment if certain basic conditions are not met. (Kruger and Serpell 2010). The “Delta society”, One of the largest organizations in the United states, which is responsible for the organization and provision of animal assisted programs , has adopted the following definitions regarding the inclusion of animals in the therapeutic context (Delta Society 2008).

Dog Assisted Therapy

Dog therapy can help improve human health by having a positive impact on physical health, social, mental and cognitive functions. Dog therapy is important in the fields of mental health, educational institutions, rehabilitative centers, hospitals, medical facilities and research. Dog therapy can reduce participant anxiety and pain, alleviate their depressive symptoms, increase their activity and improve their mood. Animal assisted therapy does not depend on any particular psychological theory. But it can be incorporated into a wide variety of methods [Delta society, 2008, Friedmann and son, 2009].

Dogs Assisted Activities

Dog assisted activities involve using specially trained dogs to enhance quality of life through motivational, educational, recreational, or therapeutic benefits delivered by trained professionals or volunteers. Ethical issues that arise in particular therapy dog programs are the potential exploitation of dogs as a therapeutic tool. One risk is that dogs may be seen only as tools to provide emotional or therapeutic support, rather than as individuals with their own needs and desires.

In the dog assisted activity content participants were able to develop interest in themselves, other residents and their environment due to feeling of ease and the development of one- on- one relationships with the dog assisted activities (Karamura, Niiyama niiyama, 2009, kruger and Serpell, 2010, Crippa and feijo, 2014).

Dogs Assisted Intervention

It is a type of therapy that uses trained dogs to support physical, mental and cognitive health. Dogs are used in the field of this therapy. This is done by taking samples from patients in the hospital. This helps in building a bond between the patient and the patient gains control over his vocal processes. A trained curer is called a sedative. Dogs help people with hearing impairments or hearing loss. For example, some people who are physically challenged or disabled can be alerted to moving around or to other dangers. Dogs sometimes work with trained clinicians to provide goal- directed interventions for people with mental condition, autism or physical disabilities. Living with a dog provides comfort, affection and emotional support, as well as fostering social interaction. Dogs also help humans interact with one another. Some people are unable to perform tasks on their own. So dogs can also assist with physical tasks like cleaning doors and picking up objects. Dogs be cognitively beneficial for people with autism, PTSD or traumatic brain injury. These potential benefits stem from in a potent, supportive source. For the patient due to the acceptance and positive response of the animals to him (Yap, Scheinberg, Williams, 2017, AVMA, 2018). The benefits of animals assisted therapy extend to various area of patient personality namely emotional cognitive, social and physical functions (Amerine and Hubbard 2016).

Emotional Support and Stress Relief

Interaction with dogs during Therapy has a positive effect on the physiological state of the patient helping the patient to feel calm and relaxed during their therapy session. Dogs are a tangible source of pleasure and consolation. When humans are faced with a stressful or unknown situation the hypothalamic pituitary adrenal (HPA) axis is activated and the steroid structure hormone Cortisol is released. Human stress responses in dogs result in the release of cortisol from the HPA axis. Interestingly, studies in humans examining stress biomarkers found that cortisol levels are reduced when people engage in interacting or stalking with a dog. Sensory stimulation in both humans and dogs can activate oxytocin and reduce cortisol elevations in humans. However, it is important to consider the role of other physiological systems and increase has been observed at times in dogs. When a person is stressed he is unable to make social relationships and his self-confidence starts to decrease. So a person should engage in exercise, meditation, enjoyable activities and dogs help a lot in this. Dogs help a lot in exercising with them and doing enjoyable activities (reading, listening to music or spending time in nature etc).

The Science behind Dog Therapy

How is the science behind dog therapy connected? Science is important for human life like the internal and external functions of the body are related to

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biology. The flow of in the human body completes most hormones functions in the body when dogs are domesticated, the person living with them starts walking with them. The body of a person secretes a lot of hormones called oxytocin, dopamine and serotonin which help a person to remain happy. Helps in having and stress hormone cortisol is reduced which keeps humans away from anxiety, depression, stress and other mental diseases. The company of animals makes them socially strong and helps in increasing self-confidence.

Improve Social Skills

Mental illness largely cuts the patient out of his social environment not only because of his stigma but also because of the reduction of skills necessary for the social interaction of human and the establishment of normal social relations. Dog's therapy helps in some important points of the person which are as follows:

- Greater self-control.
- Enhanced problem solving skills.
- Increased must empathy and teamwork.
- Improved willingness to be involved in a therapeutic program or group activity.
- Increased focus and attention.
- Increased self-esteem and ability to care for one.
- Reduced blood pressure, Depression and risk of heart attack or stroke.

Benefits of Dogs for Mental Health

How are dogs beneficial for mental health? And they help in reducing stress, anxiety and depression. The physical benefits of dog assisted therapy include pain reduction, reduced blood pressure and improved motor skills mobility, improved respiratory punching, increased social interaction and decreased heart rate. Dogs never let their owners feel alone they always like to be with them and help them.

Includes Dogs for Mental Therapy

Emotional Support Dogs (ESD): Provide comfort and companionship to people with emotional challenges. Ex- Golden Retrievers, Labrador Retrievers & Poodles etc.

Therapy Dogs: Trained to visit hospital schools and elderly homes. Ex- German Shepherds, Pugs & Cavalier king Charles Spaniels etc.

Service Dogs: Specially trained for individuals with disabilities (Ex- PTSD (Post Traumatic stress disorder & Cerebral palsy) service dog. Ex- Golden Retrievers are Labrador Retrievers are common.

Anxiety and Depression

Pets can reduce work – related stress. Two out of three employee & college students say work stresses them out and 40% say their job gets in the way of their health. Studies show that pets in the workplace help reduce stress and improve employee satisfaction. It helps manage anxiety. Now more than ever, many people are feeling anxious or struggling with mental health. Pet provides companionship and support. Pets can help you be more active. They give you a reason to get out side, get some fresh air and get active, which is proven to improve your mood, sleep and mental health. This cohort study examines the association of dog and cat attachment with depression and anxiety scores in middle- aged and older women, in particular those who reported experiencing abuse as children. A tight link between the patient and the animals is often created, and it is a source of support and motivation for commitment to the therapeutic procedure, At the same time, contact with animals improves the social skills of patients with depression, breaking the limits of his potential marginalization and providing opportunities for the course of treatment (Horwitz, 2010, Cheung and Kam, 2017). In conclusion, the treatment of depression with animal assistance may present positive and encouraging results as data from various surveys and studies show, the need for further study in this field becomes imperative for the general acceptance and establishment of the method.

Autism

A serious developmental problem is that impairs the ability to communicate and connect with other. Autism affects nervous system. A person's intelligence, emotional, social and physical health is widely affected. Dog therapy can have positive effects on children with autism. The hormonal changes caused by contact with animals improve and increase children’s social interactions, even in children who have developed profound isolation from the environment and the people around them (Hanson et al, 2007, Foden and Anderson, 2011, Siewertsen, French, Tremato, 2015, Borgi et al, 2016).

The most important benefit of the treatment is to improve the communication and social skills of children as well as to control and limit stereotypical behavior. Dealing with animals can also increase the child’s strength and improve the areas of fine and gross motility. Animals are not only an incentive for children to engage in activities, but also a model for their own learning. The therapeutic involvement of animals such as dogs, horses, rabbit and dolphins has been found to the most effective in the field of developmental disorders of children and adults. Due to the physiology and kinesiology of the horse, therapeutic riding also presents additional benefits in terms of improving the motor functions of autistic patients (Bass, Duchowny, Llabre, 2009, Wang, 2013,).

Managing Risk, Challenges & Considerations

Many issues have been raised regarding the health risk presented by dogs in therapy dog programs. Potential risk to humans includes transmission of allergens, envenomation, scratches and bites. However, the health and well-being risks to the participants have been less considered. Not all people are comfortable with dogs, some people are afraid of dogs and some people develop allergies from contact with dogs and their pets, so this is a challenge in itself. However, Participants coming into contact with the therapy dog may contract pathogens carried by the dogs and the health risk may be increased. Feeding a raw meat diet and the subsequent possibility of zoonotic transmission is also an important consideration. Understanding of the risks involved appears to be limited as only 13% of small therapy organizations in the USA have a policy that prohibits feeding dogs a meat diet. The most common health protocols outlined for therapy dog programs are the need for regular veterinary visits and vaccinations for which many people are unable to provide medical care. Health checkups include swab and nasal cultures. Vaccinations including canine distemper, parainfluenza, parvovirus hepatitis and rabies preventative treatment include flea and tick control and heart worm.

III. CASE STUDIES AND RESEARCH

This study also so that dog therapy can help in reducing PTSD patient. And by therapy into our lives we bringing dogs can make life more comfortable. Dogs are often used in biomedical research to study heart and lung disease cancer and orthopedics. The Ottawa charter could be revised to advocate for animal friendly policies to enable the integration of animal assisted therapy programs within health settings in acute and community settings. Evidence based standards of practice have been developed internationally to ensure minimum protection for animals engaged in animals assisted therapy programs, including animal assisted therapy. Dogs are used in cardiac studies because their heart size and connectivity in similar to the human heart.

IV. CONCLUSION

Therapy dog programs can benefit a wide variety of individuals who may need support, companionship and assistance in managing their health and well-being. The important role played by therapy dogs in enhancing the lives of humans is well documented. To ensure the future sustainability of therapy dog programs for people requiring therapy, transparency and assurance of good animal welfare is a key priority. Its implementation in somatic disorders such as depression, autism, dementia & PTSD etc. can lead to changes in their personality behavior, and physical health.

Although research using animals to treat human disease is prohibited. It needs to be broadened and enriched. But at the same time obvious weakness and drawbacks need to be addressed. So that its potential strengths can be taken into account and the therapy can be established as a real and important step in the future.

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ASSESSING THE IMPACT OF WATER POLLUTION: CAUSES, CONSEQUENCES AND SUSTAINABLE SOLUTIONS

Abstract

Water pollution is a huge concerning environmental issue that threatens ecosystems, public health, and economic sustainability. This research paper explores the major causes of water pollution, including industrial waste, agricultural product runoff, and domestic waste, while analyzing their far-reaching consequences on aquatic life, human health, and biodiversity. The study also examines various sustainable solutions, such as wastewater treatment, pollution control policies, and community-driven conservation efforts, to mitigate the adverse effects of water contamination. By integrating scientific research, policy analysis, and technological advancements, this paper aims to provide a significant understanding of water pollution and propose effective strategies for sustainable water resource management. The findings highlight the urgent need for global cooperation and stringent regulatory measures to make sure the availability of clean and safe water for our upcoming generations.

Water pollution remains a significant global challenge, driven by human activities such as industrial release of effluents, agricultural runoff, and improper waste disposal. This study systematically investigates the primary sources, chemical and biological

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pollutants, and their impact on our aquatic ecosystems, human health, and socio-economic stability. By analyzing case studies and recent advancements in pollution control technologies, the research highlights the effectiveness of wastewater treatment, bioremediation, and policy interventions in mitigating water contamination. Furthermore, this paper evaluates the role of environmental regulations, sustainable industrial practices, and community engagement in addressing this crisis. The findings of the chapter underscore the urgent need for interdisciplinary collaboration and innovative solutions to ensure long-term water quality management. This research contributes to the growing discourse on sustainable water resource management, advocating for integrative approaches to combat water pollution effectively.

Keywords: Water pollution, public health, industrial discharge, agricultural runoff, domestic waste, anthropogenic activities, bioremediation, sustainable practices.

I. INTRODUCTION

Hazardous substances that pollute the water bodies cause deterioration in water quality and this is what we call water pollution. There are three primary sources of this form of contamination. The first, natural sources, are thermal and acidic discharges from volcanic regions, which are, however, relatively rare. The second source of the emissions are domestic waste, including sewage and wastewater of laundry activities in households, apartments, and other residential areas. In rural and some suburban areas this waste is often handled on an individual household basis where the waste percolates into the ground partially treated or untreated. However, domestic waste in urban areas is generally collected through sewage systems and then directed either to treatment plants or in some cases into water bodies without treatment—being one of the main drivers of water pollution [Boyd and Tucker, 2012].

In urban areas, sewage management is the responsibility of local government agencies which makes it generally easier to manage. On the other hand, industrial waste production has varying degrees of variability across sectors and geographic locations. Dairy production and food processing industries produce waste with a high organic content which can occasionally be treated like domestic waste. On the other hand, the waste from industries like chemical manufacturing, mining, and textiles contain low organic content with high amounts of hazardous substances such as heavy metals, acids and alkalis [Nesaratnam, 2014; Williams et al., 2015].

II. CAUSES OF WATER POLLUTION

Water pollution negatively impacts both humans and the environment, with over 14,000 deaths daily due to untreated sewage in developing countries. Contaminated water also affects human health by transferring disease-causing bacteria and viruses into freshwater, affecting consumption and crop and livestock feed. Excess plant nutrients can cause algae blooms and weed growth, disrupting water’s ecological balance and causing acid rain and ocean acidity [Ravindra Kormal Chand Jain, 2022].

Excessive use of insecticides/pesticides and chemical fertilizers in farming activities leads to water pollution, causing groundwater leaching and surface water bodies affecting aquatic ecosystems[Kumar et al. 2021].Industrialization and urbanization significantly contribute to environmental degradation and pollution, negatively impacting water resources like surface and groundwater,

which are essential for life[Sarker et al. 2021].Wastewater is a significant environmental problem due to the frequent violations of WHO's water quality criteria for surface and groundwater. The rapid urbanization, industrialization, and population growth are major factors contributing to the worsening situation of declining fresh water availability [Ayesha Tariq C Ayesha Mushtaq, 2023].
Sewage water is a major public health issue in third world countries due to lack of integrated sanitation networks. Coastal cities receive wastewater without treatment, leading to health issues. Untreated cesspits and household pesticides can breed diseases. Untreated wastewater can cause serious health issues, especially when it leaks into drinking water, containing microorganisms like bacteria, viruses, and parasites [Suaad Hadi Hassan Al-Taai, 2021].

Plastic pollution, another factor contributing to water pollution, has grown into a global environmental crisis. The build-up of plastic waste in oceans, lakes, and rivers threatens marine creatures and ecosystems. The presence of microplastics, defined as plastic particles smaller than 5 mm, in drinking water sources around the world has prompted worries about the potential severe health implications.

Water pollution is a broad and complex issue that stems from a variety of sources, including industrial, agricultural, urban, mining, and plastic pollution. A unified and thorough approach that includes regulatory actions, enforcement of pollution control regulations, investment in wastewater treatment facilities, and public education and awareness campaigns is necessary to tackle water pollution. By addressing the sources and factors of water pollution, we can ensure the health and well-being of individuals and ecosystems globally and protect water resources for future generations [Shyma Chandra Yadav, 2024].

III. ENVIRONMENTAL AND HEALTH IMPACTS OF CONTAMINATED WATER

Water is most important for life on this planet, but water pollution is a serious concern to human health as well as to the environment. Water containing contaminants may affect aquatic organisms as well as human populations. Disruption of the fragile equilibrium within aquatic ecosystems is a critical consequence of water pollution. Unpolluted water is necessary to survive for fish and other organisms, and pollutants can cause harm or death to them, thus disturbing the food chain and reducing biodiversity. Water pollution also leads to the proliferation of hazardous algal blooms which poison marine life and release harmful substances into the environment [Kazmi et al. 2022].

Polluted water is a threat to human health since it can contain harmful viruses, bacteria, and parasites that may cause a different disease such as gastrointestinal infections, respiratory disease and dermatological diseases. Long term exposure to some chemicals and heavy metals can result in severe neurological impairments, cancer and reproductive health problems [[Shetty et al. 2023],[Gonsioroski et al. 2020]]. Particularly acute for populations who rely on contaminated water sources, these are the health hazards.

Water pollution is more detrimental to human health and ecosystems as the environment is more interconnected. Contaminants from a particular source can move to other water bodies far from the point of contamination [Lu J.,2021]. Foods that we eat or that are contaminated by chemicals that are discharged into rivers may eventually end up in the ocean and contaminate seafood and degrade marine ecosystems. This emphasizes the necessity to deal with water pollution across the globe In order to avoid the devastation of ecological integrity and public health.

In addition, communities that rely on clean water for fishing, agricultural, tourism and other purposes will face major economic hardship due to the pollution. Contaminated water health issues can lead to lower agricultural production, depleted fish stocks, lower tourism income and thus higher health care costs. It further intensifies existing social disparities as it becomes increasingly difficult for people with little financial means to secure access to clean water and necessary medical care.

Preventive and corrective measures for tackling the problem of water pollution are required [Prata et al. 2019]. The stringent enforcement of regulations to protect water quality includes controlling pollution at its origin by preventing industrial effluents and agricultural runoff from becoming sources of pollution. Furthermore, stormwater management systems and advanced wastewater treatment systems must be deployedto limit the introduction of contaminants into aquatic ecosystems. It is essential to promote sustainable water management practices to protect our ecosystems and human health from long term adverse effects.

Clean water is essential to supporting both ecosystems and human health. Water pollution is a serious threat that threatens not only human populations but also the biodiversity in aquatic environments. The water pollution consequence is wide because of the interrelationship of global ecosystems and communities. In the implementation of sustainable approaches and proactive interventions aimed to mitigate water pollution, it is possible to protect for the future generations and preserve the ecosystems that support life. For future generations, it is essential to guarantee access to clean drinking water because it is a fundamental right to all living organisms[Shyma Chandra Yadav, 2024].

IV. PREVENTION OF WATER POLLUTION

The prevention of water pollution requires short- and long-term steps to overcome the difficulties in tackling the pollution which is already impacting the society in a very dangerous manner, water-borne diseases in humans as well as in animals is very common nowadays, if controlled immediately then only we would be able to save it for future generations.

The following steps could be taken to mitigate the pollution of water-

The construction of Sewage treatment plants in cities, workable in full capacity, decentralized wastewater system, nature-basedsolution. [UN-water (2018)World Water development report]

The treatment of industrial waste water should be done with full efficiency and it should be made liable for punishment if any shortcoming is found in treating the wastewater as the level of toxicity is very much on the higher side and it turns out to be a disastrous for flora and fauna. For e.g. heavy metals nutrient such as ammonia, mercury, oil and grease. [George Tchobanolous; FranklinL.Burton et al;2003].

The rain water harvesting should be made mandatory for every household so that storage of water could be more and more.

Diffuse pollution of waterways can be reduced by minimizing or avoiding use of chemicals in agriculture, and domestic activities [Zeyneb Kılıç, 2021].

Minimize plastic consumption and promote water conservation [Rozina Khatun, 2017].

Technologies are being used to treat nitrogen and phosphorus in wastewater manage and dispose of solid and liquid waste, recycle agricultural waste, and restore wetlands To control pollution method like combining, physical, chemical ,biological and ecological techniques are applied to prevent blue algal blooms. ecological restoration efforts focus on using plants to clean polluted water by growing aquatic vegetation ,such as tall water plants, floating leaf plants, submerged plants [J. Qu C M.Fan, 2010].

Education and awareness are critical components of global efforts to reduce water pollution. By raising awareness about the hazards of water pollution and the steps individuals can take, we can help people all around the world protect their water resources. Organization promotes the idea that clean water is a valuable resource that must be protected for future generations through campaigns, workshops and community engagement activities [Shyma Chandra yadav, 2024].

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IMPACT OF AIR POLLUTION ON DIABETES MELLITUS

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Abstract

Air pollution is a critical and manageable risk factor for diabetes and hence there is need for awareness about air pollution at society and at government level. Exposure to air pollution has been shown to adversely impact on health a number of biological pathway and type 2 glucose metabolism. Since several high quality papers on air pollutant and type 2 Diabetes(T2D) have been published beyond the last reviews. I review epidemiological studies to quantify the association between air pollutants and T2D. The aim of my study was to assess the effect of environmental air pollution on incidence of type 2 Diabetes mellitus (T2DM).

Methods: In this study I identified 110 published studied through a systematic database search including PubMed, Google Scholar, ISI-web of science and EMBASE.

I searched the related literature by using the key terms including air pollution, occupational and environmental pollution, gaseous, NO2, particulate matter pollutant PM 2.5 and PM 10 and Diabetes mellitus. Descriptive and quantitative information were extracted from the selected literature. Finally, I included 19 publications and remaining studies were excluded.

Results: Air pollution is associated with dysregulation of glucose metabolism. Air

pollutant e.g. PM and NO2 are associated with higher odd of type 2 Diabetes mellitus (T2DM). Air pollution is well known to goes inflammation. Particulate matter less than 2.5 μm can pause inflammation and these inflammation can leave to damage Insulin producing β-cell in spleen, and these inflammation can also increase Insulin resistance. In this way they lead to Diabetes mellitus.

Conclusions: Particulate matter 2.5, Nitrogen Dioxide (NO2) exposure to these air pollutants are significantly associated with increased risk of type 2 Diabetes mellitus (T2DM).

It is suggested that environmental protection officials must take high priority steps to minimize the air pollution. One important step we have taken in our country is we are like now moving towards hybrid and electric cars, so this will probably decrease at least NO2, hence to decrease the incidence of type 2 Diabetes mellitus (T2DM).

Keywords: Type 2 Diabetes mellitus, air pollution, Hyperglycaemia, PM 2.5.

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I. INTRODUCTION

1. Background

Diabetes mellitus is a metabolic disorder. A group of metabolic disease are put together due to certain commonalities and these common threads are tendency for chronic hyperglycaemia leads to Diabetes mellitus.

It is life-long disease and swiftly increasing in all age groups and in both genders. It include many physiological functions, organs and multiple systems and in associated with wide ranging and devastating health complications. International Diabetes Federation's 6th addition of the Diabetes Atlas, which indicates that global prevalence of Diabetes is 8.3% which means that 382 million adults are diabetic, and number is expected to rise to 592 million by 2035. IDF also estimated that as many as 183 million people are unaware that they have diabetes.

2. Problem Statement

Air pollution is a growing global threat affecting millions of people. It contributes to the development of a wide range of acute and chronic respiratory and coronary artery diseases. While the burden of respiratory and cardiovascular disease has been well established, some literature indicates that air pollutants also contribute to impaired glucose metabolism, insulin resistance and type 2 diabetes mellitus. It has also recently been hypothesized that long-term exposure to air pollution is a risk factor for type 2diabetes but still the association remains unclear due to the conflict results. Therefore, the present study aim to assess the effect of environmental air pollution on incidence of type 2 Diabetes mellitus.

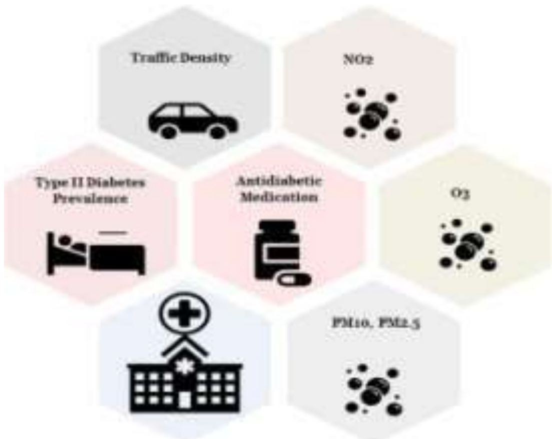

Figure 1

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3. Significance of the Study

This study offers a fundamental insight into how environmental pollutants contribute to diabetes, and offers important lessons for policymakers, health care professionals and city planners who wish to reduce the burden of disease through improved air quality standards.

Figure 2

II. LITERATURE

1. Overview of Diabetes

Diabetes is a chronic condition where the body either dosen't produce enough insulin or can't it properly, leading to high blood sugar levels. It is metabolic disorder, a group of metabolic disease are put together due to certain commonalities and these common threads are tendency for chronic hyperglycaemia leads to diabetes mellitus.

Symptoms

- Frequent urination
- Excessive thirst
- Fatigue
- Blurred vision

Types of Diabetes

Type 1: Autoimmune disorder, insulin deficiency.

Type 2: insulin resistance and lifestyle-related factors.

Gestational Diabetes: It occurs during pregnancy.

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Common symptoms include excessive thirst, frequent urination, fatigue, and blurred vision

2. Air Pollution and Health Impacts

Major air pollutants: PM2.5, PM10, NO_2, SO_2, CO, O_3.
Established links with respiratory, cardiovascular, and metabolic disorders.

3. Biological Mechanisms Linking Air Pollution to Diabetes

The connection between air pollution and diabetes involves multiple physiological pathways:

- **Systemic Inflammation:** Inhalation of PM. and other pollutants activates inflammatory responses, releasing cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-a). Chronic inflammation impairs insulin signaling, contributing to insulin resistance, a hallmark of type 2 diabetes.

- **Oxidative Stress:** Pollutants generate reactive oxygen species (ROS), which damage pancreatic beta cells responsible for insulin production and disrupt glucose metabolism.

- **Endothelial Dysfunction:** Air pollution compromises vascular health, reducing blood flow to insulin-sensitive tissues like muscles and adipose tissue, further exacerbating insulin resistance.

- **Autonomic Nervous System Imbalance:** Exposure to pollutants may alter the balance between the sympathetic and parasympathetic nervous systems, influencing glucose homeostasis.

Experimental studies in animal models demonstrate that PM2.5 exposure leads to visceral fat inflammation and reduced insulin sensitivity, while human studies suggest that traffic-related pollutants like NO, correlate with higher fasting glucose levels.

4. Epidemiological Evidence

A growing body of evidence supports the association between air pollution and diabetes:

- **Longitudinal Studies:** Research from the United States and Europe has shown that individuals living in areas with higher PM. concentrations

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have a significantly increased risk of developing type 2 diabetes. For example, a 10 µg/m² increase in PM_2., exposure has been linked to a 10-20% higher diabetes incidence.

- **Urban vs. Rural Disparities:** Urban populations, exposed to greater levels of traffic-related pollution, exhibit higher diabetes prevalence compared to rural counterparts, even after adjusting for socioeconomic factors.

- **Vulnerable Populations:** Children, the elderly, and individuals with pre-existing conditions like obesity show heightened susceptibility to pollution-induced metabolic dysfunction.

III. METHODOLOGY

The present study was conducted in the department of zoology, T.D.P.G. college, Veer Bahadur Singh Purvanchal University, Jaunpur, Uttar Pradesh. In this study I identified 110 published studies through a systematics database searches.

Secondary data from PubMed, Google Scholar, IST-web of science and EMBASE.

I searched the related literature by using the key terms including air pollution type 2 diabetes environmental pollutants, diabetes risk, PM10, Pm2.5 and NO2.

Again from WHO, CDC and environmental monitoring agencies.

Analysis of air quality indices and diabetes prevalence data.

Surveys and interviews with healthcare professionals and affected individuals.

No limitation on publication status, study design or language of publication were imposed. I reviewed 110 papers, finally I included 19 studies and remaining studies were excluded from the study.

1. Ethical Considerations

Confidentiality and anonymity of survey respondents.

Compliance with institutional ethical guidelines for health research.

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IV. RESULTS AND DISCUSSION

1. Statistical Findings

Trends showing a positive correlation between air pollution levels and diabetes prevalence.

High-risk zones with elevated PM2.5 levels reporting higher diabetes cases.

2. Public Health Implications

The link between air pollution and T2DM has far-reaching implications for public health. With more than 463 million individuals globally currently living with diabetes (according to recent estimates), and air pollution impacting billions, the intersection of these two epidemics is its magnified combined burden. Complications arising from diabetes—cardiovascular disease, kidney disease, and retinopathy—are already debilitating and expensive; pollution-driven elevations in prevalence will further tax healthcare systems. In addition, the economic impact, such as lost productivity and cost of treatment, highlights the need to resolve this problem.

This evidence also suggests a preventable aspect of the diabetes epidemic. In contrast to genetic susceptibility, air pollution is a modifiable risk factor. Minimizing exposure may decrease T2DM incidence, providing a double benefit of enhanced respiratory and metabolic health.

For example, areas that have enforced strict air quality regulations, such as Europe and North America, experience slower increases in diabetes rates than less-regulated regions.

3. Discussion

Air pollution is a big problem for our health, and it's becoming a major reason for diseases like Type 2 diabetes. When we talk about air pollution, we mean the harmful things in the air—like tiny dust particles called $PM_{2.5}$, gases like nitrogen dioxide (NO_2), and other chemicals that come from cars, factories, burning fuel, and even plastics. Breathing this dirty air for a long time can harm our body in many ways, and one of the biggest issues is that it increases the risk of Type 2 diabetes.

How does this happen? When we breathe in polluted air, these harmful particles and gases enter our body. They cause swelling (inflammation) inside us and create stress in our cells. This makes it hard for insulin—a hormone that controls our blood sugar—to work properly. When insulin doesn't work well, our blood sugar levels go up, and over time, this can lead to Type 2 diabetes. Studies, like the ones by Park and Wang, have shown that people living in areas with high levels of $PM_{2.5}$ and NO_2 are more likely to get diabetes. Another study by Eze found that air pollution can even harm the tiny energy factories in our cells (called mitochondria), which makes the diabetes problem worse.

The problem is bigger in cities than in villages. In urban areas, where there's more pollution from traffic and industries, the number of people with Type 2 diabetes is much higher. For example, research shows that in cities, 15.4% to 14.5% of people have Type 2 diabetes, while in rural areas, it's only 3.1% to 8.6%. This difference is because city air is much dirtier.

In places like Delhi or other big cities in India, the air quality is really bad, and the number of diabetes cases is also very high. Studies also found that kids exposed to polluted air have a higher chance of getting diabetes when they grow up, which is really worrying.

There are many reasons why air pollution leads to diabetes.

Things like smoking, eating unhealthy food, and not exercising already make diabetes more likely, but air pollution adds to the problem. For example, a study by Brook showed that air pollution can make diabetes worse by increasing the risk of heart problems, which often come with diabetes.

Another study by Thiering found that long-term exposure to air pollution can mess with how our body handles sugar and cause inflammation, which leads to diabetes. Even in Canada, where air pollution isn't as bad as in India, researchers found that NO_2 and $PM_{2.5}$ still increase the risk of diabetes, especially in women.

Air pollution doesn't just cause diabetes—it's also linked to other health problems like lung diseases, heart issues, and even cancer. Researchers have found that the longer you're exposed to polluted air, the worse it gets.

For example, a study showed that women living near busy roads, where pollution is high, have a higher chance of getting diabetes compared to those living in cleaner areas. This shows how serious the problem is, especially for people in cities.

But there's hope! If we work on reducing air pollution, we can lower the number of people getting diabetes. This means making strict rules for factories and vehicles to reduce smoke, using cleaner fuels like CNG, and planting more trees to clean the air.

Governments and communities need to work together to make the air safer. For example, if we reduce $PM_{2.5}$ levels in cities, it can help lower the risk of diabetes and other diseases.

Also, people can take steps like wearing masks on polluted days, staying indoors when air quality is bad, and eating healthy to protect themselves.

In the end, air pollution is a big challenge, but it's something we can fight. By cleaning up the air, we can not only reduce diabetes but also make life healthier for everyone. It's not just about the environment—it's about saving lives and keeping people healthy for the future.

V. CONCLUSION AND RECOMENDATIONS

Being exposed to air pollutants greatly increases the chances of developing type 2 diabetes mellitus. When people are exposed to these pollutants over a long period, it triggers inflammation in the lungs and visceral fat tissue, leads to insulin resistance, and eventually results in type 2 diabetes. These observations highlight a significant public health concern for communities worldwide. It's recommended that health authorities create strategies to reduce air pollution in order to lower the number of diabetes cases.

1. Summary of Key Findings

Strong association between air pollution exposure and increased diabetes risk.
Biological mechanisms supporting pollution-induced metabolic dysfunction.
Socioeconomic factors exacerbating the impact of pollution on vulnerable communities.

2. Policy Recommendations

Policy Recommendations: In order to counteract the effects of air pollution on diabetes, health authorities need to give top priority to policies that decrease emissions and enhance air quality. Some of the major strategies are:

- **Tighter Emission Standards:** Implementing restrictions on industrial and vehicle emissions to lower PM2.5 and NO2 concentrations.
- **Urban Green Initiatives:** Increasing green areas and encouraging low-emission modes of transport such as electric vehicles and cycling.
- **Public Awareness Campaigns:** Informing communities of the connection between pollution and diabetes, promoting preventive strategies such as indoor air purifiers.
- **Health Monitoring:** Incorporating air quality into diabetes prevention initiatives to detect and assist high-risk groups.

Coordination among environmental agencies, healthcare providers, and policymakers is essential in order to effectively implement these measures. International agreements, like the Paris Agreement, may also include prevention of diabetes as a co-benefit of climate action since the drivers of pollution and GHG emissions are shared.

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AIR POLLUTION STRESS DUE TO AUTOMOBILE STRESS IN JAUNPUR

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Abstract

The rapid development of urban India has resulted in a tremendous increase in the number of motor vehicles. In Jaunpur, vehicle numbers have doubled over the past decade. This surge, driven by rapid urbanization, has significantly impacted human health and the environment. Motor vehicles are now a leading source of urban air pollution and key contributors to anthropogenic carbon dioxide and other greenhouse gas emissions. The transport sector accounts for nearly 90% of total emissions. Air pollution has become a major environmental and public health issue in India, linked to a wide range of health effects including respiratory issues, nausea, skin irritation, birth defects, immune suppression, and cancer. These alarming outcomes underscore the urgent need for technological interventions to combat vehicular pollution.

This paper reviews the vehicular emission stress in Jaunpur city and examines the various technological and policy developments aimed at reducing emissions. It explores air quality assessments, current emission control legislation and standards, the roles of key regulatory bodies, and advances in fuel quality. Emphasis is placed on emerging technologies such as electric vehicles (EVs), hybrid engines, catalytic converters, particulate filters, and the implementation of Bharat Stage VI (BS-VI) emission norms. The paper also discusses intelligent transportation systems (ITS), real-time emission monitoring, and alternative fuels like compressed natural gas (CNG), biodiesel, and hydrogen. The overall impact of these measures is assessed, and future strategies for sustainable urban transport and vehicular emission reduction are proposed.

Keywords: Vehicular Pollution, Air Pollution, Emission Control Technologies, Electric Vehicles, Catalytic Converters, Alternative Fuels, Air Quality, Sustainable Transport

I. INTRODUCTION

Air pollution is one of the most serious environmental concerns in urban Asian cities, including India, where a large portion of the population is exposed to poor air quality. The health-related impacts of air pollution—such as respiratory diseases, increased cancer risk, and other serious ailments—are well known and thoroughly documented[1]. Beyond health impacts, air pollution also leads to significant economic losses, particularly due to the financial resources required to provide medical care for affected individuals. The economically disadvantaged are often the most vulnerable, as they lack adequate means to protect themselves from harmful pollutants[2].

Jaunpur district is located in the northwest part of the Varanasi division in Uttar Pradesh. Its elevation ranges from 261 ft to 290 ft above Mean Sea Level (MSL), with temperatures fluctuating between 4.3°C and 44.6°C. Like many other Indian cities, Jaunpur is undergoing rapid urbanization. It is projected that the majority of India’s population will reside in urban areas within the next two decades. Given that poor ambient air quality is primarily an urban issue, this trend is expected to directly impact millions of city dwellers[3].

The rapid urbanization in Jaunpur has also led to a dramatic increase in the number of motor vehicles, with the vehicle fleet nearly doubling over the past decade. While increased mobility brings economic benefits, it also comes at a high environmental cost. Motor vehicles have now become the primary source of air pollution in urban areas, largely due to traffic congestion and outdated technologies.

Although air quality can be improved through a mix of technical and non-technical measures such as legislative reforms, institutional policies, and market-based instruments India faces unique challenges in addressing urban air pollution[4]. These challenges stem from transportation characteristics that differ significantly from those in developed countries, including the widespread use of older vehicles, inefficient road networks, and shared space among motorized vehicles, pedestrians, and non-motorized traffic in cities like Jaunpur.

Vehicles in India are often older and use technologies that have been phased out in many developed nations[5]. In addition, the institutions responsible for managing urban air quality are not as advanced or well-resourced. Nevertheless, the country has undertaken several important initiatives to improve urban air quality. These include enhancing fuel quality, enacting and enforcing vehicle emission standards, and improving traffic planning and management[6].

On the non-technical side, efforts include public awareness campaigns about the economic and health impacts of air pollution, encouraging the use of cleaner fuels, promoting the purchase of vehicles equipped with advanced emission control technologies, and strengthening institutional frameworks and capacity for monitoring vehicular emissions[7].

Vehicular Pollution: Vehicular pollution refers to the release of harmful substances into the environment by motor vehicles. These pollutants have numerous adverse effects on human health and the ecosystem. Transportation is a major contributor to air pollution in many cities worldwide due to the large number of vehicles on the roads. Increased purchasing power has made cars more affordable, which negatively impacts the environment. In India, vehicular pollution has grown at an alarming rate due to rapid urbanization. Air pollution from vehicles in urban areas particularly in large cities has become a critical concern[8].

The effects of vehicular pollution are increasingly evident, manifesting through symptoms such as cough, headaches, nausea, eye irritation, bronchial issues, and reduced visibility.

Vehicular Pollution in Jaunpur: Air pollution is a major environmental concern in urban cities like Jaunpur, where the majority of the population is exposed to poor air quality. Rapid urbanization in India has led to a dramatic increase in the number of motor vehicles[9]. As vehicle numbers continue to grow and traffic congestion worsens, motor vehicles have become the main source of air pollution in Jaunpur. In response, India has taken several steps to improve air quality in urban areas[10].

These measures include:

- Improving fuel quality
- Enforcing vehicle emission standards
- Enhancing traffic planning and management[11]

Vehicular Pollutants: Automotive vehicles emit a variety of pollutants, depending on the quality of fuel used and engine efficiency. Emissions also include fugitive fuel emissions, which vary based on vehicle type, maintenance, and usage[12]. Major pollutants released from vehicles include:

- Carbon monoxide (CO)
- Nitrogen oxides (NOx)
- Photochemical oxidants
- Air toxics (e.g., benzene, aldehydes, 1,3-butadiene)
- Lead (Pb)
- Particulate matter (PM)
- Hydrocarbons (HC)
- Sulfur oxides (SO_2)
- Polycyclic aromatic hydrocarbons (PAHs)[13]

Petrol/gasoline vehicles mainly emit hydrocarbons and carbon monoxide, while diesel vehicles predominantly emit nitrogen oxides and particulates.

Key Ingredients of Vehicular Pollution

- **Ozone:** A major component of urban smog, formed when hydrocarbons and nitrogen oxides react with sunlight. Though beneficial in the upper atmosphere, ground-level ozone irritates the respiratory system, causing coughing, choking, and reduced lung capacity.

- **Particulate Matter (PM):** Tiny particles of soot, metals, and pollen that give smog its murky appearance. Fine particulates can penetrate deep into the lungs and pose serious health threats.

- **Nitrogen Oxides (NOx):** These pollutants cause lung irritation and compromise the body's defenses against respiratory infections like pneumonia and influenza. They also contribute to ozone and PM formation.

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- **Carbon Monoxide (CO):** An odorless, colorless gas produced by burning fossil fuels. Vehicles account for nearly two-thirds of CO emissions. CO interferes with oxygen transport to the brain and organs, posing significant risks to infants and those with chronic illnesses.

- **Sulfur Dioxide (SO_2):** Produced mainly by diesel engines, this gas can form fine particles in the atmosphere and affect children and asthmatics.

- **Hazardous Air Pollutants (HAPs):** Toxic chemicals released by vehicles, refineries, and fuel stations, which can cause serious health effects.

Reasons for Increasing Vehicular Pollution in Jaunpur

1. High vehicle density in urban centers
2. Older vehicles dominate the vehicle population
3. Dependence on private vehicles, especially two-wheelers and cars, due to inadequate public transport, leading to idling emissions and congestion
4. Lack of land use planning, causing longer travel distances and higher fuel consumption
5. Inadequate inspection and maintenance facilities
6. Fuel adulteration and poor fuel quality
7. Poor traffic management and deteriorating road conditions
8. High levels of pollution at traffic intersections[10]

Pollution Load from Road Traffic in Jaunpur: The vehicular pollution load was estimated in a joint study conducted by the Central Road Research Institute (CRRI), the National Environmental Engineering Research Institute (NEERI), and the Indian Institute of Petroleum (IIP) in 2002. The study focused on four key pollutants: carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), and particulate matter (PM) in urban areas of the most densely populated cities. The findings indicated that Delhi had the highest vehicular pollution load in the country, attributed to the largest number of automobiles operating there[14].

Table 1: Estimated Pollution Load in the cities (2020)

City	Pollution Load in Metric tones per day			
	CO	NO_X	HC	PM
Delhi	412.84	110.45	184.37	12.77
Mumbai	189.55	46.37	89.93	1058
Kolkata	137.50	54.09	47.63	10.80
Chennai	177.00	27.30	95.64	7.29

Banglore	207.04	29.72	117.37	8.11
Hyderabad	163.95	36.89	90.09	8.00
Kanpur	28.73	7.25	11.70	1.91
Agra	17.93	3.30	10.28	0.91

Serious Effects of Vehicular Pollution

1. **Global Warming:** One of the major consequences of vehicular pollution is global warming. Vehicles emit greenhouse gases into the atmosphere, contributing to the depletion of the ozone layer and a rise in global temperatures. This increase in atmospheric temperature leads to extreme weather conditions such as heavy rains, floods, and severe heat or cold, which in turn result in loss of life, destruction of property, soil degradation, and negative impacts on agriculture[15].

2. **Poor Air Quality:** Vehicular pollution has severely degraded air quality. In some countries, people are forced to wear face masks to reduce the inhalation of harmful substances. In the United States, for instance, vehicles account for about one-third of the nation's air pollution[16]. Living in such polluted environments is uncomfortable and poses serious health risks, with the air saturated with harmful pollutants that drastically lower the air quality index[13].

3. **Reduced Visibility:** Emissions from vehicles, especially older models or heavily loaded trucks, can produce thick smoke that significantly reduces visibility. If you're driving behind such a vehicle, your visibility may be impaired, even if only briefly[17]. In cities with dense traffic and high pollution levels, visibility issues are worsened by fog, which, when combined with smoke, creates smog posing additional hazards to road users.

4. **Health Issues and Complications:** Vehicular pollutants can lead to a variety of health complications, including lung infections, respiratory problems, and cancers[18]. Hydrocarbons are particularly harmful they can affect the heart, damage the central nervous system, aggravate asthma, and, in severe cases, lead to premature death. It's estimated that around 5,000 people die annually from lung cancer and heart attacks linked to vehicle exhaust fumes. Additionally, treating these illnesses places a heavy financial burden on families and causes emotional distress. Oil spills from vehicles further damage plant and animal life, including marine ecosystems. The broader health of a population is at risk, potentially impacting the economy as productivity declines[19].

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5. **Acid Rain:** Vehicles emit nitrogen oxides, which contribute to the formation of corrosive smog, leading to rusting of vehicles and corrosion of buildings and infrastructure[15]. When nitrogen oxides dissolve in rainwater, they produce acid rain, which can damage limestone and marble structures, reduce the usability of harvested rainwater, and harm plant growth[20].

Table 2: Effects of different pollutants on environment and human health

Pollutants	Effecton Environment	Effect on human health
Carbon Monoxide (CO)	N.A.	Harmful for cardiovascular system, central nervous system, pregnant women, and young children. Causes nausea, headaches and drowsiness.
Nitrogen Oxides (NOx)	Causes acidrain. Harmful for fertilization of soil.	Affects respiratory system. Increases vulnerability to infections and lung disease. Causes initations in noses and eyes
Sulphur Oxides (SO)	Causes acidrain. Reduces visibility.	Harmful for lungs.
Particulate Matter	Reduces visibility. Creates dirty locality due to dusts.	Causes irritation in lungs and long tem disorder. Alters immune system.
Lead	NA	Causes damage to brain, lower IQ in children and death.

It Affects Tourism: Because of the adverse effects of vehicular pollution, especially the formation of smog, tourism ends up being affected. Most people are not willing to change their mindsets and become more proactive, a lot of good things can be achieved. In the same manner, vehicle pollution can also be reduced and managed.

II. CONCLUSION

In this age of rapid advancement, air pollution caused by automobiles has become a critical environmental concern. Today, in almost every country, the majority of the population is exposed to poor environmental quality. Human beings have become increasingly vulnerable to a wide range of diseases, from mild ailments like headaches to severe conditions such as lung cancer. This, in turn, leads to significant economic losses for the country, as financial resources must be allocated to provide medical assistance to the affected population.

Pollution from motor vehicles can be minimized through the adoption of new and innovative technologies, the use of alternative fuels, and the implementation of effective government policies. These measures, if applied properly, can significantly improve environmental conditions. The present study also offers guidance to automobile manufacturers in creating a more sustainable and environmentally friendly future.

It is often said that we only have one Earth, and we must do everything possible to protect it. We cannot afford to remain passive spectators because pollution affects everyone— even those who do not directly contribute to it. Vehicular transportation is one of the leading causes of air pollution globally. The good news is that meaningful change is possible, beginning with individual responsibility toward building a cleaner planet.

When people visit Jaunpur, poor air quality could pose serious risks to their health and even lead to premature death. A decline in tourism due to environmental concerns results in a loss of foreign exchange income and economic opportunity21,22. Air pollution is one of the most pressing environmental issues in urban areas of Jaunpur, where a majority of the population is exposed to unhealthy air. Health-related problems such as respiratory diseases, increased risk of cancer, and other serious conditions are well known and documented19. Beyond the health impacts, air pollution also results in significant economic burdens, particularly in the form of healthcare costs required to treat those affected. The economically disadvantaged are often the most affected, as they lack access to adequate protection or treatment options.

The air pollution level in Jaunpur can be significantly reduced through the use of technical innovations and alternative fuels. With proper implementation, the negative health effects associated with these pollutants can be greatly diminished.

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ENVIRONMENTAL STRESS AND GLOBAL CHALLENGES IN THE PRESENT CONTEXT

Abstract

In the contemporary era, environmental stress and global challenges have reached critical levels due to the rapid pace of industrialization, urbanization, and the unsustainable exploitation of natural resources. These activities have severely disrupted the Earth's ecological balance, resulting in complex and interconnected crises such as climate change, biodiversity loss, pollution, deforestation, and natural disasters. Climate change, driven by the increased emission of greenhouse gases since the Industrial Revolution, has emerged as one of the most pressing global threats, manifesting through rising temperatures, melting polar ice, extreme weather events, and declining agricultural productivity. Air and water pollution, exacerbated by industrial emissions, vehicular traffic, and improper waste disposal, pose significant risks to public health and the environment. The depletion of freshwater resources, combined with growing population demands, has intensified water scarcity and threatens food security in many regions.

Deforestation continues to accelerate habitat loss, biodiversity decline, and global warming, while inefficient waste management contributes to plastic and e-waste crises. These environmental issues also have severe socio-economic consequences, including increased inequality, displacement, and conflict over resources. Although global initiatives like the Sustainable Development Goals and the Paris Agreement aim to mitigate these challenges, their effectiveness depends on collective

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global action, robust policy implementation, and grassroots participation. Education, innovation, and sustainable practices must be integrated into all levels of society to address these urgent problems. Ultimately, solving environmental stress requires a united, cross-sectoral effort involving governments, institutions, communities, and individuals to secure a sustainable future for all.

Keywords: Environmental stress, climate change, deforestation, industrial emissions, pollution

In the present times, environmental stress and global challenges have become highly complex and multidimensional. Industrialization, urbanization, and uncontrolled exploitation of natural resources have deeply impacted the ecological balance of the Earth. Climate change, biodiversity loss, air and water pollution, deforestation, desertification, and the increasing number of natural disasters are issues that have become serious threats to all of humanity.

Climate change is one of the biggest challenges in the world today. Since the Industrial Revolution, there has been an unprecedented increase in the emission of greenhouse gases, causing global temperatures to rise consistently. Its effects can be seen in the rapid melting of polar ice, rising sea levels, extreme weather changes, and agricultural productivity. Many countries are involved in international efforts, such as the Sustainable Development Goals (SDGs) and the Paris Agreement, to mitigate the dangers associated with climate change, but there is still a need for solid policies and their effective implementation on a broad scale.

Air pollution has also become a serious environmental issue. Increased industrialization, rising vehicle numbers, and uncontrolled use of fossil fuels have elevated the levels of harmful gases in the atmosphere. As a result, respiratory diseases, lung cancer, heart disease, and other serious health problems are arising. In particular, in countries like India and China, the Air Quality Index (AQI) in major cities has reached alarming levels. According to the World Health Organization (WHO), millions of people die prematurely each year due to diseases caused by air pollution.

The condition of water resources is also extremely concerning. The demand for water is rapidly increasing due to growing population and industrial use, but the availability of clean water is steadily decreasing. Issues such as water pollution, the flow of industrial waste and plastic waste into rivers, and the decline in groundwater levels are exacerbating the water crisis. In many developing countries, the lack of clean drinking water has become a major health crisis. The water crisis is also directly affecting the agricultural sector, leading to food security problems.

Rampant deforestation is also a major cause of environmental stress. Millions of hectares of forests are being destroyed for the expansion of urbanization and industrialization, causing not only harm to biodiversity but also accelerating climate change. The reduction in forests is destroying the natural habitats of wildlife, causing many species to approach extinction. Deforestation has also led to a decline in carbon dioxide absorption, further enhancing the greenhouse effect.

The growing industrialization and urbanization have made waste management a serious problem. The uncontrolled spread of plastic waste, the increasing volume of e-waste, and the unorganized disposal of industrial waste are severely impacting the environment. Plastic pollution in oceans and rivers has become a global crisis, causing significant damage to aquatic life. Many countries have adopted waste management and recycling policies, but their impact is still limited.

The social and economic impacts of environmental stress are also profound. Due to climate change, the reduction in agricultural production, rising food prices, and conflicts related to the water crisis are increasing economic inequality. Environmental disasters are displacing people, especially in poor and developing countries, leading to refugee crises. Environmental instability has also increased the likelihood of conflicts and wars over natural resources.

On a global scale, various efforts are being made to ensure environmental protection and sustainable development. The United Nations' Sustainable Development Goals, the Paris Climate Agreement, carbon credit systems, the spread of renewable energy, and the development of green technologies have seen many countries take concrete steps. However, the success of these efforts is only possible if the global community unites to solve these problems collectively.

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Social awareness and citizen participation can also play a significant role in reducing environmental stress. Steps like adopting a sustainable lifestyle, reducing plastic use, promoting energy conservation, encouraging afforestation, and adopting sustainable agricultural systems can be taken by ordinary people. Governments should also implement strict environmental policies and prioritize sustainable development.

Environmental problems can also be addressed through education and research. New technologies, such as solar and wind energy, water conservation techniques, and the use of biodegradable materials, can help reduce environmental damage. Cooperation between the scientific community and policymakers can provide effective solutions to the environmental crisis.

Environmental protection is no longer just the concern of scientists or policymakers; it has become the responsibility of every individual. If we want to ensure a safe and balanced environment for the present and future generations, we must bring about positive changes in our policies, behaviors, and lifestyles. Solving environmental stress and global challenges is not the responsibility of just one nation or organization; it is a collective responsibility of all humanity.

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IMPACT OF ENVIRONMENTAL STRESS ON MENTAL AND EMOTIONAL WELLBEING OF STUDENTS

Abstract

Climate change has had a profound impact on mental health and emotional wellbeing of students. Climate change means increasing temperature, sea level rise, unpredictable agriculture, and frequent natural disasters. All these things affect students' learning - from lack of access to resources to uncertainty in life. Lack of resource access and uncertainty further affect mental peace, mental stability and emotional wellbeing of a person. Mentally and emotionally well, students are a resource for our society. That is why it is important to know the reason which affects it. In this study literature reviews have been done to study the effect of climate change on the mental and emotional well being of students.

Keywords: Climate change, Mental Health, Air pollution, sustainable development.

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I. INTRODUCTION

According to World Health Organisation (1948), health means complete mental, physical, emotional wellbeing of a person and not only absence of disease in a person, that is why, The United Nations proposed sustainable development goals(SDGs) which focus directly or indirectly on the health of human beings. Sustainable Development Goal (SDG)3(Good Health and Wellbeing) explicitly includes target related mental health and wellbeing. Other than SDG 3 other SDGs also focuses upon mental health, for example, SDG1 talks about irradiation of poverty, as marginalisation affect mental health negatively; SDG4(Education): Education helps to understand oneself better and provide solution to improve mental health; SDG5(Gender Equality) and SDG10 (Reduced Inequalities) is also related with mental health. This shows mental health of a person is clearly related with his/her environment Environment could be anything from home to climate. In recent research, Jaquim Radua 80 Found the effect of climate change on mental wellbeing. They have done literature review and found there is a direct negative impact of climate change and air pollution on mental health. In recent years, air pollution has increased in cities. For example, in Delhi AQI (Air Quality Index) has reached above 200 which is an unhealthy level. Poor air quality has a profound negative impact on mental health (Nobile F. et. al., 2023). Climate change has become drastic, wildfires in the USA in January 2025, floods in Europe 2024, drought in sub-Saharan regions are a few examples of severe climatic conditions. Climate change also resulted in loss of biodiversity which directly or indirectly affected the health of human being.All these things are impacting life of human beings and leads to displacements, poor living conditions, scarcity of basic resources. In a study by Funk, he has found that El Nino (2014\15) event increased crop production losses from drought. Flood, Cyclone, Wildfires are a severe risk to food systems like crop, livestock fisheries. With less rain agriculture productivity is decreasing, due to excessive heat and water shortage livestock productivity is declining. Further, lack of quality food leads to the risk of malnutrition and malnutrition in children leads to poor cognitive development. All disturbances in human life affect not only their physical wellbeing but their mental health too. Situations created by climate change have a significant negative impact upon academic life of students and create existential crises in their life which leads to mental distress for students. A mentally and emotionally well student is a resource for society which can further improve the condition of society and environment by increasing productivity, peace, and health in people’s life. Good mental health is not only important for students’ personal growth but overall growth of society.

II. METHOD

A systematic literature review has been done in this research. For this research data were obtained from identifying the literature on this topic with a inclusive reading of many related literature to understand the way through which climate change can affect mental health and found many terms related to mental wellbeing and climate change: depression, anxiety, ecoanxiety, eco-paralysis, solastalgia, psychoterratic, wildfires, cyclone, drought, floods, heatwave, climate migration, forced displacement. The researcher searched search engines like Google Scholar, PubMed, Research Gate to get the information. Data has been taken from research conducted between 2014 and 2024. In this process researchers went through abstract and full papers to screen the eligibility of paper for relation of climate change with mental health and emotional wellbeing of students and then synthesize the result according to that.

Environmental Stress and its Effect on Mental Wellbeing

Mental and emotional wellbeing definition: Mental health not only means absence of illness but it also includes the ability of a person to cope up with challenges, realize their potential, manage their emotions, have a good quality life, connect with others.

Ways through which mental health of students are affected by climate change: Climate change can affect mental health in many ways, it can be direct or indirect. Direct pathways include experience of heatwaves or floods. Indirect pathways include inaction of government or witnessing climate related damages. These effects of climate change on mental health and emotional wellbeing can be for a short duration or for a longer time. Effect of environmental stress can become more severe when sexual violence, force migration takes place due to this.

Due to the direct and indirect impact of climate change on the mental health of students, it is difficult to measure the true effect which provides a research gap in this area.

While we are going to study the effect of many Environmental factors on the mental health of students, it is important to be aware of what are the factors which affect mental health and wellbeing of students. Adversity, quality of their home life, violence, socio-economic problems are some of the main factors which affect mental health and wellbeing of students.

Mental health condition of some students becomes severe due to lack of support, discrimination, unavailability of basic needs, forced marriages. Due to Environmental stress many risks emerge including disruption to infrastructure, loss of loved ones, which leads to mental distress to students. According to IPCC Sixth Assessment working group 2nd report on impacts, adaptation and vulnerability (2022), Each and every part of the world will face increased risk of floods, wildfires, food and water scarcity, disruption in ecosystem, loss of biodiversity which will affect normal life of human beings. Unavailability of schools, livelihood, loss of houses. All these things will bar students from getting education and destabilizes their future which will develop mental stress in students. As we can see, environmental factors can have a significant impact on students' mental wellbeing. Here are some environmental factors which affect mental health and emotional wellbeing of students.

Extreme Weather Conditions: Floods, Wildfires, cyclones disrupt schooling of students. A person having continuous exposure to natural disasters experiences an increase in post traumatic stress disorder and depressive disorder (Patwary. M.M. et. al.,2024).Area prone to frequent change in climatic condition have irregular schooling of students due to which students are not able to properly pursue their education which further result in lower self esteem, less social connectivity, loneliness resulted in mental stress.In case of flood, wildfires, cyclone, hurricane people may lose their occupation, house, loved ones which may lead to instability in students' life which leads to mental stress.
Poor air quality: We are well aware about poor air quality; it is the cause of increasing respiratory disease in students. Also, some studies have shown that air pollutants PM 2.5 and PM 10 is the cause of increasing mental health such as depression and anxiety (ZundelC.G et.al., 2016). Particulate matter can travel through the respiratory tract to the brain causing inflammation and affect cognitive ability. Physical activity has a positive impact on students' mental health, reduces anxiety and depression, and improves moods. But due to poor air quality, regular exercise is not possible for students. students cannot move in open spaces which bar their creativity and expansion of their brain (Radua J. et.al,2017).

Heat Waves: Extreme heat can make it difficult for students to concentrate, at the same time create physical health issues like nausea, faint, digestive disorder, all these things barb students from attending school regularly. At some places due to heat waves school may need to be closed which makes it harder for students to keep up with their peers which develops anxiety in students (Rony M. K. K. et. al.,2023). Heat waves are also a reason for food quality depletion, because heat wave loss of livestock and food production takes place which further become a reason for issues like malnutrition in students.

Limited Access to Nature: Climate change has a serious impact on biodiversity and natural habitats and leads to lack of green spaces. Humans have an inherent inclination towards Nature and forest green spaces have a positive impact on the mental health of humans. It has been suggested that nature is beneficial to children’s ability to make friends with peers, self confidence and produce a greater sense of self-esteem (Amoly et. al. 2014). Green spaces also motivate humans to do physical activity. But reducing green cover may increase depression, anxiety and reduce creativity, affecting their cognitive development.

Water Scarcity: Due to climate change and misuse of water, quality and quantity of water has been decreased. Decreased amount of seasonal rain, disappearing and polluted lakes and rivers are very common nowadays, Because of which amount of usable water is not available as per the demand. It has been found that poor water quality or less quantity of water is an important psychosocial stressor to users. Psychosocial distress is also related to the abstract dimension of water insecurities (Watichetal, 2020). Waterbornedisease affectsstudents’ physical health and in the long term their mental health. Water insecurity leads to social exclusion and economic hardships which are again a cause of mental trauma. In case of water scarcity inadequate sanitation takes place, which increases anxiety and disgust among students (Aihara et. al.,2016; Boating et. al.,2022).

Food Insecurity: Climate change is a big reason for shortage of food. Inadequate food access can cause anxiety and stress which can affect students’ mental health. Adult and child food insecurity significantly correlated with stress (Ling et. al., 2022). Reduced food security leads to higher risk of chronic diseases and chronic disease triggers stress, depression, sleep disorder etc. Climate change and use of fertilizers and pesticides also have a negative effect on food nutrition (Tagkas C.F. et. al.,2024). Unavailability of nutritious food also has a negative impact on mental health. For example, insufficient protein can affect cognition and energy level of students, low iron leading to fatigue, irritability (Sato H. et. al.,2020; Rupanagunta G.P. et. al., 2023)

In conclusion, Environmental stress affects students’ mental health and their cognitive development in one way or another. There is a need to address every challenge from food insecurity to decreasing green spaces.

III. CONCLUSION

Climate change can have both direct and indirect impact on the mental health of students.

Climate change can also have a long term impact on the mental wellbeing of students. For example extreme weather conditions can develop conditions from anxiety related issues to livelihood issues in students and can affect their ability to concentrate and learn. Loss of biodiversity can impact their learning ability. With the current global trend of global warming and climate change, there is a need to address the global health crisis and maintain students' mental health and emotional wellbeing. There are some areas where workers need to be done. It is crucial to reduce emission at source and strengthen environmental governance. There is also a need to reduce use of private vehicles on a daily basis and application of fertilizers. Awareness of environment protection should be increased among the public and climate change should be incorporated in literature, mathematics, science too. Schools should have weekly curricular activities which promote cleanliness habits, can increase awareness about nature and aware students and teachers toward life without harmful daily use products like plastics, lead, synthetic materials. Schools can have awareness programs to encourage students to reduce their carbon footprint through practices such as conserving energy, using public transport. Awareness seminar should be arranged and full guidance should be provided to students. At the community level also the government should start a program so that people can understand their responsibility about the environment and understand its effect on mental health. For the mental health of students, social support and public policies can help to build resilience in students and reduce impact of environmental stress on mental health of students. Action from the government is needed for providing socio psychological health services for students affected from environmental stress. Students also need to adjust their lifestyle and habits to cope up with climate change while maintaining their mental health. Mental health is closely related to physical activity so students should be physically active. Exercise increases good hormones (Sharma A. et. al.,2006) in the body, which alleviates the mood of a person. Students should also make friends and have some social activity.

In summary Mental health of students is very important not only present but for our future also,for that reason comprehensive measures are needed ranging from reduce air pollution to reduce use of hazardous substances which affect mental health to spreading awareness about mental health of students, increase social harmony.

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STUDY OF PHYSICOCHEMICAL CHARACTERISTICS OF SUGARCANE SOIL AND PRODUCTS IN THE VARANASI

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Abstract

Sugarcane (Saccharum officinarum) is a vital commercial crop in India, significantly supporting the nation's sugar and ethanol industries. The Varanasi region of Uttar Pradesh, renowned for its nutrient-rich alluvial plains, holds a prominent position in sugarcane cultivation. The physicochemical attributes of soil—such as pH, texture, mineral content, and organic matter—play a pivotal role in determining the crop's growth, yield, and quality. These soil parameters also influence the efficiency and quality of sugarcane-derived products like juice, molasses, and ethanol. This study seeks to evaluate the soil properties in the sugarcane-cultivating zones of Varanasi and explore their correlation with the production potential and quality of sugarcane and its by-products, thereby offering insights into optimizing agricultural and industrial outputs.

Soil samples from selected sugarcane fields in Varanasi were examined for key physicochemical parameters, including pH, electrical conductivity (EC), organic carbon (OC), and macronutrients—nitrogen, phosphorus, and potassium. Findings revealed predominantly neutral to slightly alkaline soils (pH 7.1–8.3), with moderate OC and varied nutrient levels. Potassium was adequate, but nitrogen and phosphorus were deficient, potentially limiting growth.

Higher OC levels enhanced sucrose concentration, improving juice quality. Soil fertility significantly influenced molasses and ethanol yields. The study underscores the need for region-specific soil management through balanced fertilization and organic enrichment. Further investigation into precision farming practices is recommended to optimize sugarcane productivity and quality.

Keywords: Sugarcane soil Fertility, Physicochemical properties, Sugar quality, Varanasi agriculture, Soil management, Electrical conductivity.

I. INTRODUCTION

Soil serves as a fundamental medium for plant growth and provides essential support for both human and animal activities. Soil health, synonymous with soil quality, refers to its inherent potential as a dynamic living ecosystem that sustains life—plants, animals, and humans alike. To meet the nutritional demands of crops, soils are commonly enriched with organic manures, chemical fertilizers, and composts. As a natural body, soil comprises organic matter and minerals, structured into distinct horizons of varying depths. These layers exhibit differences in morphology, chemical composition, parent material, and biological properties, making soil a complex and vital component of Earth's ecosystem.

The soil in the study area is well-suited for the extensive cultivation of high-yielding crops like sugarcane. Soil samples were collected from agricultural fields across Varanasi. A total of five samples from each soil sub-group—topsoil (0–10 cm) and subsoil (10–25 cm)—were obtained from five distinct locations. Sampling was specifically conducted in sugarcane-growing fields to assess soil characteristics across varied sites within the region.

In addition to analyzing sugarcane cultivation, this study also aimed to assess the concentration of heavy metals in soil. Conducted in the rural regions of Varanasi, Uttar Pradesh, the research involved evaluating both topsoil and subsoil from sugarcane fields for heavy metal content, pH, electrical conductivity (EC), organic carbon (OC), and macronutrients (nitrogen, phosphorus, and potassium). The presence of heavy metals in soil and their accumulation in sugarcane crops were examined to estimate potential health risks for the local population consuming contaminated produce. The study further analyzed sugarcane juice quality, focusing on pH and sugar composition. Results indicated that higher organic carbon levels enhanced sucrose content, thereby improving juice quality. Additionally, soil fertility had a direct impact on molasses and ethanol yields. To enhance sugarcane productivity, region-specific soil management strategies—such as balanced fertilization and organic matter enrichment—are essential. The findings also highlight the need for further research in precision farming practices.

II. MATERIALS AND METHODS

The study was conducted in the Varanasi district of Uttar Pradesh, India, a region well-known for its fertile land and rich agricultural tradition. Agriculture forms the backbone of the local economy, with a few industries also established in this part of the state. The district receives an average annual rainfall of approximately 982 mm, supporting the cultivation of major crops such as rice, wheat, barley, and sugarcane. The predominant soil types in the area include deep loams, sandy soils, and clay loams, characteristic of the alluvial plains of the Ganga River. Soil fertility varies across the region, ranging from moderate to poor.

The climatic conditions in Varanasi are generally mild, warm, and temperate, with consistent rainfall even during the driest months. For the study, surface soil samples were collected randomly from different villages across the district. Samples were taken from a depth of 0–15 cm using a V-shaped notch. These samples were thoroughly mixed, and 500 grams from each site were processed for analysis. The soil was air-dried, crushed with a wooden roller, and sieved through a 2.0 mm mesh. The processed samples were then sealed in labelled polythene bags and transported to the laboratory for further examination.

The pH of the samples was measured in a 1:10 (w/v) aqueous solution using a digital pH meter (Systronics). Electrical conductivity (EC) was determined with a digital conductivity meter. Total organic carbon (TOC) was estimated using the partial oxidation method by Walkley and Black (1934). Total and exchangeable sodium (exchNa) and potassium (exchK) were analyzed as per Simard's methodology (1993). To sustain agricultural productivity, especially for crops like sugarcane, the application of nitrogen, phosphorus, and potassium (NPK) in appropriate proportions and quantities tailored to specific soil-climatic conditions is essential.

The available nitrogen in soil was determined with the help of Kjeldahl semi auto-analyse which was described by Subbiah and Asija (1956).

$$\text{Available N (kg ha}^{-1}\text{)} = \frac{(S - V) \times 0.02 \times 14 \times 2.24 \times 106}{1000 \times 5}$$

S = Sample titration reading V = Blank titration reading

The available phosphorus in soil samples was estimated using Olsen's method, suitable for neutral to alkaline soils, employing a 0.5 M $NaHCO_3$ solution at pH 8.5. Available potassium was determined using a flame photometer, following the procedure by **Schollenberger and Simon (1945),** with neutral normal ammonium acetate as the extractant.

Fresh sugarcane samples were manually cleaned, weighed, washed, and uniformly cut into equal-sized pieces. Juice extraction was performed using a mechanical sugarcane extractor, with slight modifications adapted from the method developed by **Jittanit et al.** for experimental accuracy**.** The extracted sugarcane juice samples were filtered through double-layered muslin cloth to eliminate debris. Subsequently, the juice underwent pasteurization at 65°C for 10 minutes to minimize microbial contamination. Then, 0.5g of Spirulina platensis water extract was added to 250mL of pasteurized juice and aseptically bottled. The S. platensis extract was prepared following the method described by **Abu Zaid et al.,** ensuring a standardized process. The water extract was UV-treated for 20 minutes to minimize microbial contamination, as the extraction process was non-thermal. The treated sugarcane juice was refrigerated at 4°C and thawed at room temperature before testing, ensuring optimal storage and handling conditions to preserve quality and safety.

III. RESULTS AND DISCUSSION

This study shows that the values of pH ranged from 7.1 to 8.3, with a mean value of 7.526 with an SD value of 0.32 and a CV value of 4.0 % (Table 1). The EC of soil samples ranged from 0.15 to 2.75 dSm-1 with standard deviation and coefficient of variation of 0.51 and 33 %, respectively (Table 1).

Table 1: Statistical analysed data on physico-chemical parameters of soil

Soil Parameter	Mean	Range	S.D (+ or -)	C.V (%)
pH	7.56	7.1 – 8.3	0.32	4
Organic carbon (%)	1.1	0.24 – 0.96	0.21	33
EC(dSm-1)	1.35	0.15 – 2.75	0.51	33

The organic carbon content of soil samples ranged from 0.24 to 0.96 %, with a mean value of 1.1 (Table 1). The standard deviation of organic carbon content was 0.21, and the coefficient of variation was 33.

Available phosphorus content of soil samples ranged from 9.01 to 23.1kg ha-1 with an average value of 13.65kg ha-1 (Table 2).

Table 2: Statistical data on primary macronutrients of soil

Soil Parameter	Mean	Range	S.D (+ or -)	C.V (%)
Nitrogen (kg ha-1	243.67	162.5-306.3	43	17.55
Phosphorus (kg ha-1)	13.65	9.01-23.1	3.4	24.66
Potassium (kg ha-1)	225.61	112.6-306.6	51.6	22.756

Available potassium content of soil ranged from 112.6 to 306.6kg ha-1 with a mean value of 225.61 kg ha-1 (Table 2). In the study region potassium content is high, may be due to elite, rich potassium minerals found in the soil.Available nitrogen content of soil ranged from 162.5 to306.3kg ha-1 with a mean value of 243.67 kg ha-1 (Table 2).

The impact of adding S. platensis water extract on the physicochemical properties of pasteurized sugarcane juice, including pH, total soluble solids (TSS), color, and turbidity, was investigated over a 5-week storage period. Notably, a significant difference in pH values was observed between treated and control samples, potentially attributed to the instability of water-soluble phycocyanin at pH 4.63 when stored at 4°C. This finding aligns with Safari et al.'s research, which highlights the temperature-dependent stability of phycocyanin pigment during storage.

Interestingly, as the pH of the sugarcane juice increased from week 2 to week 4, a reduction in colony occurrence was observed in the total plate count. This phenomenon may be linked to the dominance of acidophilic spoilage microorganisms in regulating the pH of the juice during the initial storage period. As the pH increased, these microorganisms were significantly reduced, likely due to "base shock" or partial loss of pH homeostasis, ultimately affecting the microbial population dynamics in the juice.

IV. CONCLUSION

The experimental results indicate that Varanasi district soils have low nitrogen and phosphorus content, with potassium falling in the medium category. Given nitrogen's crucial role in plant growth, supplementing chemical fertilizers with composted manure and green manure is recommended for high-yielding crops. To address low phosphorus levels, organic amendments like raw bone meal and poultry manure can enhance phosphorus availability. Potassium, essential for disease resistance and drought tolerance, can be supplemented with pig manure. These recommendations aim to optimize soil nutrient management, promoting healthy plant growth and crop yields. By adopting these strategies, farmers can improve soil fertility and productivity.

This research successfully investigated the physicochemical properties of sugarcane juice treated with S. platensis water extract. The analysis revealed a direct correlation between pH, total soluble solids, color, and turbidity in both control and treated samples. However, microbiological assessment showed microbial growth during the middle of the testing period. Notably, the addition of S. platensis significantly lowered the pH value of sugarcane juice throughout the storage period in treated samples compared to control samples. These findings highlight the potential benefits of using S. platensis water extract in sugarcane juice preservation, particularly in maintaining physicochemical stability.

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THE RELATIONSHIP BETWEEN OBESITY AND INCREASED INFERTILITY IN WOMEN

Abstract

The spreading of obesity and overweight are increasing and has become a pandemic worldwide .Weight gain or obesity may consider as a complication of insulin treatment. There is also increasing scientific evidence regarding the role of obesity and overweight in type1 –diabetes. Obesity has determined influences on all systems, including reproductive health. The spreading of obesity in infertile women have a higher incidence of menstrual dysfunction and an ovulation .The risk of infertility, conception rates ,miscarriage rates pregnancy complications are increased in these womens. They have lousy reproductive results include go along with reproduction such as ovulation induction, in -vitro fertilization, intracytoplasmic sperm injection (IVF/ICSI) and ovum donation cycle. The expended adipose tissue impairs insulin and causes insulin resistance in muscle, liver, and other organ also. Weight- loss has favourable effects on the reproductive results in these patients.

Keywords: Infertility, IVF, pregnancy, adipose tissue

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I. INTRODUCTION

Obesity is a medical condition characterized by excessive or abnormal body fat accumulation that increases the risk of health problems. It has become a global pandemic which is present not only all over the world but also many developing and even in undeveloped countries. These conditions are commonly classified based on Body Mass Index (BMI), a simple measures that compares weight to height. Overweight is defined as BMI between 25 and 29.9. Obesity is defined as having a BMI of 30 or higher **(1).** Obesity may cause many problems such as social, psychological, demographic, hormonal and metabolic factors, medications, genetics and other health problems. Being overweight and obese increases the risk of many health problems, including cardiovascular diseases, Type2-diabetes , respiratory issues(sleep apnea) , joint problems (osteoarthritis, back pain), certain cancer (brain, colon, kidney, liver), hypertension, liver diseases (fatty liver, cirrhosis), mental health issues (depression, anxiety, low self-esteem.

Obesity also plays a significant role in reproductive disorders particularly in womens. It is related with an ovulation, menstrual disorders, and adverse pregnancy outcomes.

In obese women, gonadotropin secretion is affected due to increase of peripheral aromatization of androgen to estrogens. The sex hormone binding globulin (SHBG), growth hormone (GH), and insulin- like growth factor binding protein(IGFBP) are decreased and leptin level are increased **(2).** These changes may explain impaired ovulatory function and so reproductive health. In obese women, due to lower implantation and pregnancy rates, higher miscarriage rates, and increased maternal and fetal complications during pregnancy have a lower chance to give birth to a healthy newborn **(3-6).**

Obesity and Infertility

Obesity is defined as having a body mass index (BMI) of 30 or more than 30; obesity can negatively impact the female infertility and increasing the risk of infertility as well as complications during pregnancy, primarily due to hormonal imbalances and metabolic issues.

Obese women often have higher level of insulin and androgens (male hormone), which interfere with ovulation and egg quality, that will eventually cause infertility. Infertility defined as – The ability to conceive after one year of regular unprotected sexual intercourse. .It is one of the most frequent disorders of the reproductive system in India as well as developing countries. Vahratian and Smith (2009, (39) have found that a larger portion of women are seeking medical help to get pregnant are obese women (7). Rich-Edwards et al. 1994 found that the risk of infertility is threefold higher in obese women than in non-obese women , and their fertility seems to be impaired in both Natural and Assisted conception cycle (ART) (8). Due to obesity, the probability of pregnancy is reduced by 5% per unit of BMI exceeded 29 kg/m2 (9). There are many more regions of infertility, and out of them obesity is also causes infertility in various pathway , including impaired ovarian follicle development qualitative and quantitative development of oocyte, fertilisation , embryo development and implantation .

Grodstein et al. (10), revealed that anvoulatory infertility was higher in overweight and obese patients whose BMI was found to be greater than 26.9kg/m2.Obesity affect the HPG axis by increased conversion of androgen increases, in adipose tissue. When estrogen increases, it will cause a decrease in GnRH by negative feedback. These finding suggested that , either anovulation continue despite the regular menses , or a combination of possible adverse effects of increased androgens on the endometrium and developing oocytes and thus adverse effect of increased level of circulating leptin on the granulose and theca cell give rise to infertility.

Anovulation and Menstual Disturbance

Obesity is associated with irregular menstruation and anovulatory infertility. Having obesity can cause our body to make too many androgens, which affect our ovaries ability to produce mature follicle. Anovulation often happens due to hormones imbalance since multiple hormone contribute to ovulation, there can be many cause of anvoulation. Obesity disrupts to many function in our body like hormonal imbalance, and altered levels of adipokines and insulin resistance , which will potentially lead to menstrual disturbances . Insulin resistance and Hyperandrogemia significantly increased in obese women, particularly who have central obesity. Hyperandrogemia and Hyperinsulinemia leads to granulosa cell apoptosis, and this may have an effect on ovarian function (11). It shows that, insulin stimulated the estrogen production in granulosa cell. Insulin can also affect the FSH, which will increase the production of estradial and progesterone hormone. In simple terms we can say that, the effect of FSH on estradial and progesterone production increases by insulin.

FSH enhances the excessive androgen substrate that will particularly lead to the distribution of estrogen level in developing follicle. Most probably estrogen level increases in the developing follicle. Insulin has also the capacity to enhance the steroidogenesis by augmenting the effect of LH on granulosa cell. Now LH cell stimulates the steroidogenesis and it inhibits further mitosis processes and final differentiation of granulosa cells in the preovulatory follicle (12). The LH hormone effect on granulosa cell, and is amplified in PCOS patients by the presence of hyperinsulinemia (**30).**

As a result of the enhanced steriodogenesis due to insulin and its interaction with LH, the unfavourable milieu causes cessation of the follicle growth. Thus, premature luteinization and follicle arrest develops and leads to menstrual cycle disorder and obesity induced oligoovulation. In conclusion, both the excess androgen and excess estrogen play a role in the anovulation and menstrual disturbance in these patients.

Obesity and Miscarriage

Obesity can increase the risk of miscarriage, obesity it one of the main cause of miscarriage. Obesity increases the higher chance of miscarriage compared to normal weight. In a study, it is found that women with a high body mass (BMI) have a significantly higher risk of miscarriage whether they conceive naturally or through assisted reproductive measures.

Obesity also increases the pregnancy complications including gestational diabetes.

Miscarriage is influenced by a variety of factors-

1. **Hormonal Imbalance:** Obesity can lead to an imbalance in hormones like insulin & leptin it may affect the development of pregnancy.
2. **Chronic Disorder:** Obesity is linked with diabetes hypertension and polycystic ovary syndrome (PCOS) it is increases the chance of miscarriage.
3. **Increase Risk of Blood Clots:** Obesity associated with higher chance of blood clotting disorder.
4. **Complications in Early Pregnancy:** Obesity may also associate to other pregnancy complications.

In a study, Landres et al. (47) found increased Euploid miscarriage in obese women regardless of the listed disorder. Some endocrine disorders such as PCOS, Hypothyroidism are cause of overweight in women and it increases the chance of miscarriage (13). PCOS closely linked with obesity and it is main cause of miscarriage alone. Bellver et al **(43)** found the rise of incidence of spontaneous miscarriage with increasing BMI in patients who had been treated by various ART including embryo transfer using donar oocytes. **Metwally et al. (45)** found a higher risk of early late and recurrent miscarriage in the obese group.

Obesity and Reproductive Function

Obesity is a disorder in which excessive body fat that increase risk of health issues. Obesity significantly impact of reproductive health, affecting pregnancy outcomes. Fertility and menstrual function obesity increases the complications like infertility, miscarriage. Obesity is linked with an increased time to conception impact of obesity on male reproductive system (13-15). It is related to increase health risk such as diabetes, osteoarthritis, coronary heart disease, and hypertension and linked to various malignancies like endometrial cancer and colon cancer.

Obesity plays a significant role in reproductive disorder particularly in females. It is affected with anovulation, infertility, menstrual disorders, difficulty in reproduction, miscarriage and pregnancy outcomes. The relationship between obesity and reproductive functions has been known. We know that obesity has many negative impacts on reproductive functions. In obese women, the insulin resistance and leptin level increased. Reproductive system is a complex system and multifactorial, it is difficult to describe the mechanism of how obesity affects it.

In obese women, the level of luteinizing hormone (LH), triglycerides, insulin, estrogen are very low density; lipoproteins are increased because of these changes the HPG axis and different gynaecological effect occur (16).

In insulin resistance and leptin levels are increased and hyperandrogenemia occur in obese women due to this change in adipokine level and HPG axis, it affects the reproductive system. In obese women , reduced pregnancy rates , increased miscarriage and many pregnancy complications are occur in both natural and assisted conceptions . Obesity affects the reproductive health in many ways.

1. **Hormonal Imbalance:** It leads to hormonal imbalance, it disturbs the ovulation and menstruation.
2. **Infertility:** Obesity reduces the fertility rate in females because of decreasing the chances of ovulation, implantation, and fertilization.

3. **Menstrual Irregularities:** It affects on menstrual cycle, it causes irregular pregnancy complications.
4. **Pregnancy Complications:** Obesity increases the chance of pregnancy complications in females, it may cause gestational diabetes, hypertension. Due to Obesity, it is very hard to conceive pregnancy naturally.

Relationship between Obesity and PCOS

Obesity is a complex and multifactorial diseased characterised by excessive amount of body fat. Obesity and Polycystic ovary syndrome (PCOS) are closely related. In a research it is found that 80% are women are affecting due to PCOS. Obesity is higher prevalent among women with PCOS. PCOS is defined as excess fat around the abdominal area. Those women that suffer from PCOS, they deal with irregular menstrual cycle, acne, excessive hair growth exacerbate insulin resistance, a common feature of PCOS, which increase the risk of developing type-2 diabetes. Those women that are suffered from PCOS and obesity their disturbing ovulation and hormone production. PCOS is linked with defects in insulin sensitivity and secretion that are further exacerbated by obesity. There is strong potentially bidirectional associated of obesity with PCOS. Women with PCOS both have higher risk of obesity and greater longitudinal weight gain and obesity. Recently we found that obese, PCOS women undergo hypocaloric dietary treatment coupled with anti-androgen (Cyproterone acetate plus ethinylestradiol and metabolic drugs) (**13).**

A woman with PCOS and obesity has increased risk of developing mental disorder such as anxiety and depression. PCOS is a metabolic disorder are characterised by hyperandrogenemia. PCOS was known only to be in a hyperandrogenic state which can leads to infertility. PCOS is linked with increased risk of metabolic disorder such as hyper-insulinism, obesity, insulin resistance (17). PCOS is often associated with insulin resistance where the body does not respond effectively to insulin. PCOS is characterised by high level of androgen. Obesity can contribute to increasing the production of androgen. PCOS is associated with metabolic changes, including change in lipid metabolism and glucose which cause weight gain and obesity.

Obesity and Treatment in Infertility

Obesity, defined as excess body fat can negatively impact female fertility, and treatment often focuses on lifestyle changes and weight management to improve reproductive outcomes. It is difficult to treat anovulatory infertility in obese women, they have a lower chance of conception following ART because they require a very high dosage of gonadotropin that respond poorly to ovarian stimulation, and also they have a higher risk of miscarriage.

To overcome from reproductive problems, including fertility, weight loss is one of the effective ways among overweight and obese women. Clerk et al. (63) found that if a small weight loss, happens, in anovulatory obese infertile women, it resulted in improvements in ovulation, pregnancy rate, pregnancy outcome. So the primary offer for the obese women to overcome from ovulatory period is weight loss. However, the effect of weight loss in obese women with regular menstrual cycle is still unclear. If a obese women who suffer from infertility, try to initiate ART programme, it is very important to determine which patient will benefit from weight loss and the initiation ion of an ART programme.

Ramlau-Hansen CH, et al, 2007 found out that in most of the cases, a obese women have a partner that is also in overweight condition, that means a overweight men can also be a risk factor for a prolonged time to achieve pregnancy. **Hakonsen LB,Thulstrup AM et al 2011**, shown in a study, that if a men go for its weight loss journey it will significantly increased total sperm count and percentage of sperm with normal morphology . So, these all are some effective ways to overcome from infertility and many other disorder which are caused by obesity.

IN PCOS

1. **Weight Loss:** Weight loss reduces the chance of health related problems .weight loss is recommended for women with PCOS and obesity.

2. **Healthy Diet:** Healthy diet are low in calorie and healthy protein that fulfill the needs of body and repair the muscle, tissue and protein , is building block of body , it is important diet. Food which is highly nutritious can help reduce weight loss and improves PCOS.

3. **Regular Exercise:** The cardio exercise are clearly helpful and by this our blood circulation improves by the regular exercise, a person free from disease and it also helps in weight loss and improves PCOS symptoms.

4. **Meditation:** Meditation is boon for us. It has lots of benefits by the meditation, person feels so good, healthy and mentally strong. It may be prescribed to help with weight loss and improves insulin sensitivity.

II. CONCLUSION

Overweight and obese patients should be suggested about the importance of decreased weight in pre- pregnancy and should be promote to lose weight weight before the treatment to decrease the poor obstetrical results due to obesity. Although weight loss is the best standard of treatment in women with a high BMI, ART should not be long delayed due to increasing age. Many fertility centers have a protocol to start ART treatment ; however there are no evidence based guidelines with respect to fertility treatment in overweight and obese infertile women .

The linked between high BMI and unfavourable fertility results is known clearly. There are many proposed mechanism to describe how obesity may leads to infertility; however, the accurate pathophysiology is not clearly understood.

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USES OF INVERTEBRATE STEM/CULTURE CELLS IN ECOTOXICOLOGICAL AND DEVELOPMENTAL BIOLOGY RESEARCH

Abstract

Invertebrate animals have emerged as significant models in ecotoxicological and developmental biology due to their simple body plans, regenerative capabilities, and ease of laboratory handling. They possess pluripotent and totipotent stem cells that enable self-renewal and differentiation, making them valuable for biological research. In ecotoxicological research invertebrate stem cells, although less explored than vertebrate ones, are crucial for understanding environmental toxicity and organismal responses. Aquatic invertebrates (e.g., sponges, cnidarians, planarians, and ascidians) are commonly used in ecotoxicology due to their abundance, biodiversity, and lower ethical concerns. These organisms help in detection of pollutants like heavy metals, pharmaceuticals, and plastics at low concentrations through bioassays. For example, Hydra attenuata regeneration assays identifying pharmaceutical teratogenicity. Planarians and sponges showing altered immune and regenerative responses to contaminants. Ascidians used as bioindicators of pharmaceutical contamination due to their chordate-like development. Challenges of invertebrate models include the lack of immortalized cell lines and susceptibility to contamination in cultures, which limits long-term use. In developmental biology research invertebrates are ideal models due

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to simple anatomy, fewer cell types, and ease of observing cell-cell interactions. Groups like sponges, cnidarians, planarians, mollusks, echinoderms, and urochordates are widely used in this field. Cnidarians (e.g., Hydra, Nematostella) possess ancient signaling pathways (Wnt, BMP, Nodal), linking them to bilaterian developmental mechanisms.

Planarians demonstrate vertebrate-like neuronal architecture and offer insights into pluripotent stem cell regulation, axis formation, and tissue identity. Sponges provide clues about early multicellular evolution and animal cell lineage. Aplysia (a marine mollusk) serves as a model for memory and learning via neurotransmission pathways. Echinoderms (e.g., sea stars, sea cucumbers) display extensive regenerative capabilities and share signaling pathways with vertebrates (e.g., BMP/TGFB, HOX).

Keywords: Ecotoxicology, teratogenicity, bioindicator, pluripotent, totipotent

Invertebrate animals are now prime importance in ecotoxicological and developmental biology research. Simple body plan, easy to handle in laboratory, specific and distinct response, mosaic developmental plans etc. are some qualities make them fit for such works. Present chapter has aim to focus some light on the application of stem/culture cells derived from invertebrate animals in ecotoxicological and developmental biology research.

I. ECOTOXICOLOGICAL RESEARCH

Invertebrate animals are as valuable as vertebrate counterpart so far stem cells and their uses are concern. Stem cells derived from invertebrates may be pluripotent and totipotent with remarkable abilities for self-renewal and differentiation similar to vertebrate counterparts. Vertebrate stem cells are valuable to us in medical research because they are comparatively more nearer to us phylogenetically, and hence most of the research on stem cell is confined to these. Stem cells are very common in invertebrate animals and some are also important for us to understand various biological phenomena. For example in developmental biology stem cells derived from acoel and platyhelminth worms are particularly attractive invertebrate models for stem-cell research because their bodies are continually renewed from large pools of somatic stem cells. Apart from this aquatic invertebrates are key animal in ecotoxicological research. **Ecotoxicology** is the study of the effects of environmental stressors at all level of biological organization viz. molecule, cell, population, community, and ecosystem level. Ecotoxicology is a useful tool to assess overall environmental quality affected chemicals produced by anthropogenic sources or others as well and ultimately reaching to all freshwater and marine ecosystems and thus affect aquatic biota. Heavy metals , aromatic compounds, detergents, pesticides, plastic, pharmaceuticals, cosmetics etc. are substances which affect aquatic ecosystem. There is need of biologically meaningful indicators and biological assays for analyzing the actual impacts of pollutants on the aquatic biota.

Invertebrate animals are very important in aquatic ecosystems in terms of both number and biomass encompassing a great verity of niches [3]. It is needless to say that these animals are now greatly affected by pollutant at various levels. Many invertebrate animals are favorite model for ecotoxicological research. Wide abundance, large biodiversity and lower ethical concerns in comparison to vertebrates make these animals very fit for this purpose. Many filter feeding invertebrates such as those of Porifera filter vast quantity of water to capture food particles and in this course pollutant are also entered in their body in very low quantity such as plastics. This makes possible to assess those chemicals which are very low in concentration and its detection is not possible by other means [4]. The *Hydra attenuata* regeneration assay was used to identify the teratogenic potential of 10 pharmaceuticals identified in effluent from a large city wastewater treatment plant (WWTP). Due to remarkable regenerative capacity *H. attenuata* cultures were used for this purpose. It was found that regeneration was significantly inhibited by gemfibrozil, ibuprofen and naproxen at very low concentration and comparatively at higher concentration by bezafibrate and trimethoprim. It is suggested that these chemicals may possibly have adverse effects on pregnant women and children [5]. *Hydra vulgaris* and *Nematostella vectensis* are other two Cniderians which are very promising for ecotoxicological research. Cnidarians have important ecological roles as predators and prey in planktonic and benthic aquatic

ecosystems, and corals also act as reef builders. Thus assessment of effects of said chemicals is very important for proper functioning of marine ecosystem.
Freshwater planarians are triploblastic animal with simple organ systems and cephalic control of reproduction and behavior. They can be cultivated at low cost and exhibit a variety of sub-lethal responses and altered biological responses to many mammalian-affecting chemicals, therefore they are recommended as model systems for *in vivo* testing in neuro-, behavioural, reproductive, developmental, regeneration, cytotoxic, mutagenic and teratogenesis studies[6] . Differences in the range of phenotypic outcomes might be observed between different species of planarians exposed to the same toxicants. Cultures of Dugesia. *tigrina* species was used to study the toxicological effect of peracetic acid (PAA) compounds and active chlorine in the calcium hypochlorite Ca $(ClO)_2$ compound [7]. Cells of fresh water sponge *Eunapius carteri* have been utilized to study the viability of cells in response to popularly used washing soda. Domestic effluent, drain water and various human activities in ponds and lakes have been identified as the major routes of washing soda contamination of water. Phagocytosis and generation of cytotoxic molecules are important immunological responses offered by the cells of sponges against environmental toxins and pathogens. It was noted that Sodium carbonate exposure resulted in significant decrease in the phagocytic response of sponge cells under 4, 8, 16 mg/l of the toxin for 96 h and all experimental concentrations of the toxin for 192 h. Washing soda exposure yielded an initial increase in the generation of the superoxide anion and nitric oxide followed by a significant decrease in generation of these cytotoxic agents. Sponge cell generated a high degree of phenoloxidase activity under the experimental exposure of 2, 4, 8, 16 mg/l of sodium carbonate for 96 and 192 h. Thus washing soda induced alteration of phagocytic and cytotoxic responses of *E. carteri* was indicative to an undesirable shift in their immune status leading to the possible crises of survival and propagation of sponges in their natural habitat [8].

Ascidians are very important form phylogenetic point of view. Their tadpole larva is important to understand how chordates have been evolved, because this larva exhibit basic chordate characters. Apart from this ascidians like Ciona *intestinalis* or *Phallusia mammillata* are as suitable model toxicological assessments by exploiting their different developmental stages such as embryos, larvae and metamorphosing juveniles [9].

Solitary ascidians *Herdmania momus*, *Microcosmus exasperatus*, and *Styela plicata* were used as bioindicators of three common PhACs (Bezafibrate, carbamazepine and diclofenac). These substances have been detected in the aquatic environment world-wide. Diclofenac was most frequent, present in nine of the 11 sites with concentrations reaching 51.9 ng/g of dry weight sample (dw). Bezafibrate and carbamazepine reached concentrations of 47.8 ng/g dw and 14.3 ng/g dw, respectively. The alarming detection of such high concentrations of PhACs in ascidians along demonstrates both the extent of PhACs contamination in the region, and the potential of ascidians as bioindicators, and emphasized the urgent need for additional research into PhAC contamination sources and effects [10]. The acetylcholinesterase (AChE) activity has been studied in 4-day post-fertilization juveniles of *Ciona intestinalis* exposed to tributyltin (TBT) at 10^{-5} M using the histochemical method of Karnovsky and Roots. Relative to vertebrate tissues and organs, the development of adult form of ascidians is interesting, because the analysis of many nuclear genes indicated that the ascidians are the closest living relatives of the vertebrates. Therefore, toxicity research using different approaches could provide data for comparative studies with vertebrates. AChE is over-expressed under chemical stress and in some diseases of vertebrates. Therefore, AChE is considered a biomarker of environmental contamination. Increased expression of AChE activity in nervous-, blood progenitors- and tunic cells have been noted in ascidians. The specific AChE inhibitor, BW284C51, inhibited this enzymatic activity. The presence of AChE activity in these cells has no obvious relations to their classical functions and seems to show a behavior similar to that of other chordates under changing stimuli. These preliminary descriptions provide a basis for further studies on cellular and molecular mechanism underlying the development of adult organs and tissues of this chordate, under chemical and physiological stress conditions [11].

From above description it is clear that invertebrate animal models are very valuable for ecotoxicological research. Aquatic invertebrate primary cell cultures have been established from different tissues of various organisms such as: (i) regenerating and differentiated tissues of cnidarians (ii) tissue explants or dissociated cells from sponges, ctenophores and corals (iii) cultures from embryonic/larval stages and different organs from marine and freshwater bivalves and gastropods (iv) various shrimp (Decapoda, Arthropoda) cell types (v) regenerating organs of echinoderms (vi) tunicate buds and zooids and (vii) nervous system cells from ascidian larva (viii) heamocytes[9]. These cell cultures have been used for assessment of specific chemicals for their toxicological effects. Some drawbacks are associated with invertebrate cell culture. In spite of intensive ongoing efforts, stable and well characterized cell lines from aquatic invertebrates have not yet been established. Furthermore, immortalized cell lines of aquatic invertebrates still do not exist [13]. Apart from this cell lines from marine invertebrates are associated with the common contamination states of primary cultures with associated and symbiotic bacteria and protists. Indeed, we still lack vital information regarding aquatic invertebrate cell requirements *in vivo* before we turn to *in vitro* approaches, and detailed knowledge on *in vitro* requirements for cell types of specific taxon of marine invertebrates is fragmented, requiring much guesswork. This emphasizes the needs for interdisciplinary approaches to elucidate the conditions for long-lasting *in vitro* methodologies for marine invertebrate cells [9]. In comparison to stem cells derived from invertebrates, mammalian stem cells are well established in ecotoxicological research. Stem cells should be derived from healthy individuals and retain phenotypically and physiologically normal features during numerous subcultures. Furthermore, they support genome editing, lower apoptotic threshold, enhanced DNA repair activity, and efficient antioxidant defence [13]. In aquatic invertebrates, adult stem cells (ASCs) are involved in asexual reproduction, regeneration/whole body regeneration, torpor, induction of rejuvenation, and delayed senescence. Two types of ASCs have been recognized i.e. cells of the germline and somatic ASC lineages that are capable of tissue homeostasis, repair and regeneration of tissues and organs [9]. In most of the invertebrate animal models in sponges and cnidarians, germ- and somatic- stem cells are blurred in identity [14]. In case of vertebrates stem cells characters are well defined while invertebrate cell models are lacking in information. These drawbacks should be considered before taking invertebrate stem cells for ecotoxicological research purpose.

II. DEVELOPMENTAL BIOLOGY RESEARCH

Simple anatomy**,** limited cell types and cell-cell interaction, regulative development makes invertebrates' ideal for to understand developmental processes. Invertebrate stem cells are found throughout the body, unlike vertebrate stem cells which are associated with a regulatory microenvironment. Invertebrates can regenerate their entire bodies, and some can regenerate their heads and feet from a small piece of tissue. Various developmental processes have been well studied in different animals. Invertebrates like sponges, hydrozoans, corals, bryozoans, platyhelminthes, aschelminthes, arthropods, echinoderms and urochordates are very familiar in developmental biology. Planarians, *Caenorhabdiitis elegance*, *Ascaris*, *Drosophila malanogaster*, sea urchins etc. are very famous in this regard. While few years ago, the use of invertebrates as model organisms was limited by the paucity of "–omics" data, the situation has rapidly changed and is still changing. Today, the genomes and

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various transcriptomes of many marine/aquatic invertebrate species as well as many recombinant proteins of invertebrate origin are available [15]. The recent directive of the European parliament imposes high restriction on classical vertebrate models in biological research due to conservation and protection point of view. Studies on vertebrate cell lines may not be application to whole organisms. In such situations invertebrates (cephalopods excluded) animal model are a great hope for in vivo studies. Recent studies have shown that the best organisms for stem cell research are the marine/aquatic invertebrates. These organisms possess numerous types and lineages of stem cells that can offer, once studied in the lab, important clues to the understanding of stem cell biology. Stem cells are present in either (morphologically) simple marine/aquatic organisms, such as cnidarians, sponges, and flatworms, or in anatomically more complex taxa, such as crustaceans, echinoderms, and protochordates (urochordates and cephalochordates). Some adult MISCs (Marine invertebrate stem cells) are pluripotent, capable of developing both the germ line and somatic tissues, and are involved in asexual reproduction and regeneration. Due to their simpler morphological and tissue organization and the accessibility of some of them to genetic manipulation, marine/aquatic invertebrates are reliable and efficient model systems to investigate the molecular basis of stemness and stem cell regulation [15].

Developmental research took back sponges into spotlight. It is known that the developmental toolkit of sponges includes signalling pathways, transcription factors and cell adhesion molecules that are employed during development of more complex animals (i.e. bilaterians). Sponges are being used as model systems to study the transition from single-celled organisms to the first animals. Sponges, ctenophores, placozoans, and cnidarians have key evolutionary significance in that they bracket the time interval during which organized animal tissues were first assembled, fundamental cell types originated (e.g., neurons and myocytes), and developmental patterning mechanisms evolved. Sponges in particular have often been viewed as living surrogates for early animal ancestors, largely due to similarities between their feeding cells (choanocytes) with choanoflagellates, the unicellular/colony-forming sister group to animals. Contractile epithelia in sponges can help unravel the complex ancestry of an ancient animal cell type, myocytes, which sponges lack. Sponges represent hundreds of millions of years of largely unexamined evolutionary experimentation within animals. Their phylogenetic placement lends them key significance for learning about the past, and their divergent biology challenges current views about the scope of animal cell and developmental biology [16].

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Cnidarians have similar molecular toolkit to that of more complex animals. Developmental studies conducted on Hydra, Nematostella , Aurelia and Clytia focused light on signaling centers (organizers) and morphogenetic gradients body axis formation. Molecular studies on cnidarian development have revealed the existence of an ancient Wnt signaling center at the site of gastrulation, which was instrumental for the formation of a primary body axis and can be traced back to the common ancestor of bilaterian and non-bilaterian animals. New molecular data also suggest that the molecular vectors for the dorso-ventral and left-right body axis in bilaterians, Bmp and Nodal signaling, respectively, were already present but had different fates in the two clades. The close link of developmental processes in bilaterians and cnidarians but also their distinct differences make cnidarians an indispensable model for tackling fundamental questions in developmental biology from patterning, regeneration and other recent molecular approaches to theoretical concepts [17].

Neurons in planarian more closely resemble those of vertebrates than those of advanced invertebrates, exhibiting typical vertebrate features of multipolar shape, dendritic spines with synaptic boutons, a single axon, expression of vertebrate-like neural proteins, and relatively low spontaneously generated electrical activity. Neurochemical and histochemical data indicated the presence of several neurotransmitter-receptor systems in planarians. Moreover, a variety of experimental studies characterized specific behavioral patterns of these animals following the exposure to drugs acting on neural transmission. These findings indicated the interactions between discrete neurotransmitter-receptor systems that were originated very early in phylogeny [18].

Planarians can regenerate using a pluripotent stem cell system. This phenomenon provides a unique opportunity to understand gene regulation in the process of differentiation from pluripotent stem cells. Recently, planarian stem cells have been identified through the use of molecular markers and cell-type specific markers. The stem cells appear committed to transcribe tissue-specific genes in a position-dependent manner before migrating to the organ rudiments or blastema. It was suggested that *Hox* genes may be involved in the regulation of stem-cell differentiation in a position-dependent manner. X-ray irradiation and grafting experiments suggested that the positional cues reside in differentiated cells. These findings led us to expect that we could learn fundamental mechanisms regarding the pluripotent stem cell system by studying planarian regeneration [19]. Planarians are also fit model for the study of tissue identity specification in adult biology. Wnt and BMP signaling along with other regulatory factors are may involved in regeneration and maintenance of the body axes. Available data indicate that genes involved in positional identity regulation at key embryonic stages in other animals display persisting regionalized expression in adult planarians. These expression patterns suggest that a constitutively active gene expression map exists for the maintenance of the planarian body. Planarians thus present a fertile ground for the identification of factors regulating the regionalization of the metazoan body plan and for the study of the attributes of these factors that can lead to the maintenance and regeneration of adult tissues [20].

Mollusks are good model for study of developmental processes such as torsion and learning and memory processes. In the marine snail Aplysia californica, the defensive withdrawal of the gill in response to stimulation of the siphon has been used to explore the cellular and molecular basis of behavioral sensitization, a nonassociative form of implicit memory. Using cell culture, it was found that protein kinase A pathway and the cyclic AMP-response element binding protein CREB appear to play a critical role in the consolidation of short-term changes in neuronal activity into long-term memory storage in the gill and siphon withdrawal reflex in Aplysia[21].

Echinoderms can regenerate many organs, including limbs, disc, gut, spines and podia and, in some species, regeneration is used for asexual reproduction. This process has been studied extensively at molecular, cellular, tissue and ecological levels. Recent studies demonstrated that echinoderms have the potential to offer viable and tractable models for molecular and cellular research on regeneration. Echinoderms show nerve-dependent regeneration and regeneration in these organisms has been shown to involve growth factors. For example, the bone morphogenetic protein/transforming growth factor-β (BMP/TGFB)–signalling in brittlestars and crinoids, the HOX-signalling pathway in brittlestars and seastars, and the Ependymin pathway in the sea cucumber. These molecular pathways are repeatedly encountered during regeneration throughout the animal kingdom [22].

Thus we can say that invertebrates are very valuable animal models now a day. Ongoing development in stem cell research and genomics makes them preferred for ecotoxicological and developmental studies.

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