CHAPTER 17

ENVIRONMENTAL STUDIES

Doctoral Theses

01. ARCHANA
Effluent-adapted Microbial Consortia and Algal Biocathode Microbial Fuel Cells for Enhanced Textile Wastewater Remediation and Power Generation.
Supervisor: Prof. Vandana Mishra
Th 27240

Abstract

Textile wastewater poses a significant environmental challenge due to its complex chemical composition, especially dyes and aromatic amines, besides heavy metals and solvents. Conventional treatment methods have predominantly prioritized color removal, often disregarding the eco-toxic potential of dye metabolites. Our study aimed to mineralize dyes and aromatic amines, employing a two-step process: anaerobic degradation of azo dyes and subsequent aerobic oxidation of aromatic amines. A specialized microbial consortium was isolated, demonstrating complete mineralization of dye and aromatic amines and marked reductions in chemical oxygen demand (COD) and nitrates (70.8% and 75.5%, respectively). Emphasis on aromatic amine degradation resulted in 75% reduction in total aromatic amines and complete removal of hazardous ones such as 3-chloroaniline, 4-aminophenol, o-phenylenediamine, and benzidine. Phytotoxicity assays confirmed reduced effluent toxicity, demonstrating an eco-friendly approach to textile wastewater treatment. Beyond detoxifying textile wastewater, we aimed to develop a self-sustainable treatment process. Textile wastewater contains latent energy from organic matter, which we harnessed using microbial fuel cells (MFCs). Our meta-analysis highlighted the crucial role of cathode catalysts in determining MFC efficiency, primarily governing the terminal reduction reaction. We introduced a cost-effective biocathode with microalgae Chlorella sorokiniana as catalysts that release oxygen through photosynthesis. Sequential anaerobic-aerobic treatment achieved a remarkable 99.3% azo dye decolorization and generated a maximum voltage of 527 mV with a power density of 768 mW/m^2. Furthermore,, our microbial analysis revealed the prevalence of exoelectrogens like Pseudomonas, Geobacter, Shewanella, and Desulfuromonas in MFCs, vital for dye wastewater degradation and power generation. In conclusion, our study addresses complete mineralization and detoxification of textile wastewater. By mineralizing dyes and its metabolites, while harnessing energy via MFCs with microalgal biocathode, we offer a sustainable, eco-friendly solution for the sustainable treatement of textile wastewater, while ensuring environmental safety.

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Detoxification 4. Enhanced Treatment of Textile effluent with Microbial Fuel Cell incorporating Algal Bio-Cathode: Insights into Mirobial Community composition. Summary and Conclusion, References and Appendix.

02. GARG (Shafali)
Occurrence, Treatment and Ecological Health Implications of Per-/Poly-Fluoroalkyl Substances (PFAS) and Phenols in Textile Effluent.
Supervisors: Prof. Radhey Shyam Sharma and Dr. Ludovic Dumee
Th 27242

Abstract

The textile dyeing industry contributes significantly to India`s gross domestic products and employment generation has drawn attention due to its high environmental footprint, primarily due to the release of persistent contaminants such as phenols, per-/polyfluoroalkyl substances (PFAS)—often termed "Forever Chemicals"—and heavy metals. To address the prevailing knowledge gap concerning these pollutants` extent and ecological impacts, the present study on "Occurrence, treatment, and ecological health implications of Per-/poly-fluoroalkyl substances (PFAS) and phenols in textile effluent" was undertaken with the following objectives: (i) assessing phenols in textile wastewater and developing nature-based solution to minimize its adverse ecological impacts, (ii) investigating the occurrence of PFAS and associated heavy metals, and (iii) evaluating methods for PFAS detection and effective remediation. Textile effluent was characterized for physicochemical properties, including pH, electrical conductivity, chlorides, phosphates, nitrate, ammonia, total dissolved solids, dissolved oxygen, chemical oxygen and biological oxygen demands. Advanced techniques such as solid-phase extraction, LCMS-MS, and GCMS were used to quantify PFAS and phenols in effluent treatment plants and nearby ecosystems. Post-quantification, the treatment efficacy of peroxidase preparation from leaves of invasive Prosopis juliflora tree (MPx), was determined for treating phenols in textile effluent. MPx was found superior to conventional horseradish peroxidases (HRP) with respect to optimum pH, activator concentration, reaction time, and toxicity removal, evaluated through phytotoxicity assays. Addressing PFAS` persistence, our study pinpoints their origins, highlights effective treatment methods, and evaluates ecological impacts when present with heavy metals. Furthermore, based on a critical evaluation of different treatment methods available, nano-enabled PFAS sensing and novel treatment strategies were suggested to monitor and manage PFAS. By bridging these gaps, the study enriches our understanding of textile effluent pollution for phenols and PFAS, and the ecological impacts of their contamination, and introduces sustainable, nature-based remediation solutions, enhancing the textile industry`s sustainability.

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03. MAJUMDAR (Sudipto)
Belowground Feedbacks and Stand Characteristics Affect the Impacts of an Invader on Species Communities and Ecosystems.
Supervisor: Prof. Inderjit Singh
Th 26655

Abstract

Abiotic and biotic ecosystem factors and processes mediate invasion success of exotic species and provide them competitive advantages over native communities. In this thesis, I have studied the complexities in the impacts of an aggressive invasive species prosopis juliflora and how abiotic and biotic plant –soil feedbacks contribute to its invasiveness. In the first chapter, I simultaneously quantified the impact of prosopis juliflora on soil properties and distinct functional groups of its understory vegetation across seven diverse sites in India. My study generated evidence to suggest a shift from dominance by native herbs in the adjacent uninvaded communities to dominance by native shrubs, exotic shrubs and exotic herbs in invaded communities. These shifts were explained by increasing soil $NH_4^{+-}N$, total phenolics and PO_4^{3}-P. This emphasizes the indirect effects of under-canopy soil on vegetation. In the second chapter, I examined how soil biota associated with prosopis juliflora and native species affect seedling growth. Prosopis juliflora soil biota promoted conspecifics and another co-invader Leucaena leucocephala but suppressed its native congener prosopis cineraria. Prosopis juliflora leaf leachate containing higher levels of the amino acid L- Tryptophan than the natives, Suppressed seedling growth in sterile soil but resulted in promotion in combination with P. juliflora soil biota. Native leaf leachate had weak effects on soil to further enhance promoter effects. Only P. juliflora microbes were observed to metabolise L- Trytophan into the growth hormone indole0acetic acid at five sites. In Four of these P. juliflora microbes enhanced seedling growth. This is the first experimental evidence for a canopy-chemical regulating soil microbial effect. In addition, I was part of three publications exploring(a) the interference Potential of sorghum halepense(b) the drivers of naturalise species richness in India and (c) Pine adaptability in the Anthropocene.

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04. SARKAR (Niloy)
Development of a Nanobiosensor for Environmental Management of Lead (Pb)
Supervisors: Prof. Radhey Shyam Sharma
Th 26656

Abstract

Nanotechnology has been called the technological revolution of the 21st century. It has been put to various applications such as biomedical, defense, engineering, and consumer electronics, etc. It is only relatively recently that it has been considered for environmental applications. In the environmental field, it can serve two prominent roles: firstly as sensors for the detection of environmental pollutants and secondly as opto-active catalysts for their mineralization. The role of nanosensors has attracted great interest recently, due to their almost limitless applications especially in the environmental field, where they can facilitate rapid, accurate and inexpensive detection of analytes including pollutants. However, for the fabrication

of such nanosensors, the three major components of nanosensors, the detection element, transducer and signal analyzer must be standardized. Since there exists an almost limitless number of materials and combinations for forming nanomaterials and the properties of nanomaterials cannot be inferred from their bulk forms, there is need to fabricate such materials and evaluate their preformance for desired applications. In this thesis, we have fabricated a tenorite based aptameric nanobiosensor for the detection of lead pollutant in water and also used tenorite-based nanomaterial for the construction of nanophotocatalytic sheets for the destruction of micropollutant antibiotics in water. We have also evaluated the potential of such nanoparticles as seed primers to enhance germination efficiency and explored their nanotoxicity. We have chosen lead because it is a well-known potent neurotoxin, which has been known since ancient times. Although it is thought of as a material of the past but it is still being used presently for the manufacture of energy storage devices and its use is not expected to cease anytime in the near future. We have also chosen to study the degradation of micropollutant antibiotics in water; amoxicillin, ampicillin, and ciprofloxacin due to the fact that conventional wastewater treatment plants are not designed to remove their increasing load. They exert a direct evolutionally pressure on the microbial community, which can lead to the rise of antibiotic resistant genes (ARG) and antibiotic resistant bacteria (ARB), which have been colloquially called “super bugs”.

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05. SHAH (Kanhaiya)
Driver-Passenger Model: Understanding the Mechanism Behind Spread and Impact of Invasive Plant Species.
Supervisor: Dr. Gyan Prakash Sharma
Th 27238

Abstract

Invasive species significantly affect global biodiversity and reduce native species diversity. A number of mechanisms have been suggested to account for the dominance of invasives in recipient habitats. The dominance of an invasive species can be attributed to the ‘driver model’, where introduced species exhibit competitive ability over native species, or to the ‘passenger model’, where species exhibit resilience towards ecosystem changes that negatively impact diversity of native species. The thesis comprises six chapters; Chapter 1 forms the introduction containing pertinent information of the ‘Driver-passenger hypothesis’, along with the review of literature pertaining to two study species, i.e. Hyptis suaveolens (L.) Poit. (a dominant invader) and Ricinus communis L. (an aggressive colonizer). Chapter 2 evidently advocates that the dominance of H. suaveolens causes competitive exclusion of native herbaceous species in dry deciduous regions of Vindhyan highlands, India. Chapter 3 suggests that H. suaveolens’s enhanced light capture and resource utilization ability acts as a driver of ecosystem change thus facilitating competitive exclusion of native species in high-light conditions. Chapter 4 provides

evidence that Allee effect dynamics, a density-dependent phenomenon, plays a key role during spread of H. suaveolens and can be used as an ecological tool to manage invasive spread. Chapter 5 reports that the variability in landscape topography drives R. communis's population dynamics thus R. communis acts as passenger of ecosystem change in neo rural-urban landscapes. Chapter 6 collates findings of the study comprising of general discussion and conclusion and suggests that the 'driver-passenger hypothesis' effectively explains the mechanism of spread and impact of H. suaveolens (driver species) and R. communis (passenger species) in invaded ecosystems. The current thesis warrants that determining whether invasive species are the cause of ecological changes (drivers) or exploiting an ecological niche created by disturbances (passengers) is crucial for the management of invasive species.

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1. General Introduction 2. Spatial co-occurrence of *hyptis suaveolens* (L.) Poit. With other non-native plant species lead to invasion meltdown 3. An arrow in the quiver: evaluating plant performance of *hyptis suaveolens* (L.) poit. In different light levels 4. Wisdom of the crowd; evidence for density- dependent species fitness in *hyptis suaveolens* (L.) Poit. 5. Does landscape topography determine the Ricinus communis L. Colonization in neo urban-rural interface areas? 6. General discussion and Conclusion.

06. SHARMA (Guncha)
Microplastics: metal toxicity and life cycle assessment.
Supervisor: Prof. Chirashree Ghosh
Th 26657

Abstract

Plastic waste accumulates in terrestrial and aquatic environments, persisting as macro, micro, and nano-sized debris. Spatially diverse microplastics (less than 5mm in diameter) are widespread in the Yamuna River, with higher concentrations reported during the monsoon season. The Najafgarh drain confluence site (site 3) showed the highest microplastic load, highlighting the need for targeted interventions to reduce plastic waste and protect the river ecosystem. Landfills are also significant contributors to microplastic pollution. The adherence of heavy metals to plastic surfaces is influenced by various factors such as surface properties, plastic composition, pH, contact time, temperature, and metal concentration. Among all, lead exhibits the highest adherence to both Polyethylene (PE) and Polyvinyl Chloride (PVC). The Langmuir and Freundlich models fit the experimental data well, highlighting the importance of plastic-type and surface heterogeneity in heavy metal adsorption. Peri-urban agriculture and compost samples are observed to be contaminated with microplastics, indicating their entry into agricultural systems. In an exposure study, Durum wheat showed greater sensitivity towards microplastic-heavy metal interaction, and both wheat species exhibit reduced growth in the presence of Polyethylene, Polypropylene, and Polyvinyl Chloride. Heavy metal adherence to different microplastic types varies, and specifically, nanosized microplastics (in powder form) have a greater impact on crop growth. Overall microplastic-heavy metal interaction reduced root exudation and impacted nutrient uptake in both species. PE exposure specifically affects microbial communities, signaling pathways, and nutrient availability, while PVC inhibits root growth and alters the soil microbial community. The 14C study showed lower carbon fixation in PVC-treated bread wheat and PE-treated durum wheat at both shoot and crop levels. Research on microplastics is rapidly increasing worldwide, and microplastics have already been tagged as an alarming threat, but there exists a knowledge gap on actual concentrations, their impacts, and their sources.

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1. General Introduction 2. Invetorization of Microplastic presence in different domains of the Delhi Region3. To estimate the potential of heavy metal adherence on different plastic type in an aquatic system 4. To understand the crop-Microplastic heavy metal interaction and to assess the natural abudance of MP's in farm inputs and enticement in growth Media 5. Assessing the effect of Microplastics on carboxylation (14C), Rhizosphere modification (14C) and Micronutrient (Zn65) uptake in crop species 6. Conclusion.

07. SHARMA (Meesha)
Elevational Macro-Ecological Patterns of Aboveground and Belowground Diversity in a Western Himalayan Gradient.
Supervisor: Prof. Maharaj k. Pandit
Th 27241

Abstract

Species diversity varies from region to region and exhibit general patterns of species richness. This change in species composition is quite evident along the elevational gradient. With increasing elevation, different environmental factors also vary. Besides decrease in temperature, there is a change in humidity, precipitation, soil temperature and soil abiotic parameters, the land-use pattern and other environmental factors as we go higher up the elevation. Different organisms are impacted by the gradients in these environmental parameters, which in turn affects many ecological processes in these environments. These elements frequently have an impact on various living forms, which shapes the species diversity in a region. Although, significant advancements have been made in disentangling the above-ground diversity and its drivers, but similar information regarding soil microbes was hitherto unknown. In this study, we provide a comparative account of the elevational diversity trend of above-and below-ground communities in pristine montane ecosystem such as the Himalaya. Our results clearly suggest that plant and soil microbes exhibit unique diversity trends along elevation which may vary according to the season and the taxonomic group studied. Interestingly, plant and soil fungal diversity pattern seem to be governed by climate rather edaphic factors, while, soil bacterial assemblage composition along elevation is driven by either of these factors depending upon the season. To our knowledge, this study represents one of the first attempts to decipher the elevational diversity trends of plant and soil microbes using conventional ecological sampling techniques combined with high-throughput sequencing and statistical modelling.

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1. Introduction and background 2. The study design 3. Plant richness along the Elevational Gradient 4. Bacterial Richness along the Elevational Gradient 5. Fungal Species richness along the elevational Gradient 6. Novel planctomycetes form Himalaya 7. Summary and Conclusions.

08. SHARMA (Udita)
Ecological Responses of Microbes to Emerging Contaminants through the C-S-R- Paradigm.
Supervisor: Prof. Radhey Shyam Sharma
Th 27239

Abstract

In the Anthropocene era, the ecological equilibrium underpinned by microorganisms, pivotal players of biogeochemical cycles and ecosystem dynamics, faces perturbations from emerging contaminants such as para-phenylenediamine (PPD) and residual antibiotics. PPD, a prevalent constituent in hair dyes, elicits concerns due to its mutagenic and carcinogenic attributes, potentially disrupting environmental integrity. Simultaneously, while antibiotics have revolutionized medical therapeutics, their pervasive environmental presence manifests in cryptic ecological perturbations, especially within microbial assemblages. Therefore, the present research, entitled "Ecological Responses of Microbes to Emerging Contaminants Through the C-S-R Paradigm," was undertaken with objectives to: (i) improve the CSR model to microbial communities, thereby advancing environmental sustainability frameworks and augmenting our comprehension of microbial ecological adaptability amidst anthropogenic stressors; (ii) methodically unravel the PPD-microbe interplay, with an emphasis on interactions under varied nutritional conditions; and (iii) meticulously gauge the cascading effects of antibiotics on the structural and functional intricacies of soil microbial consortia using C-S-R paradigm. Pivotal findings unveiled that a specific strain, Acinetobacter Baumann, adeptly transforms PPD into more potent derivatives, notably the hazardous Bandrowski's base. This biotransformation, while metabolically ingenious, detrimentally impacts plant health, urging a reconsideration of wastewater treatment protocols associated with hair dye industries, particularly in burgeoning Asian industrial hubs. Moreover, the CSR model`s adeptness transcends erstwhile microbial classification paradigms rooted in trophic and reproduction/growth criteria. It furnishes a more nuanced scaffold for decrypting the multifaceted engagements between emerging contaminants and environmental microbes. Such insights elucidate the spectrum of microbial life strategies evoked by contaminant-imposed selection pressures, with profound implications for refining bioremediation efforts. In essence, the optimized CSR model not only propels microbial ecological categorization but also promises predictive ability, potentially steering ground-breaking strategies in environmental stewardship and microbial community optimization.

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09. YADAV (Arun Kumar)
Risk Assessment of Sick Building Syndrome in Relation to Indoor air Pollution in Urban Agglomeration of Delhi.
Supervisor: Prof. Chirashree Ghosh
Th 27029

Abstract

Generally, indoor air is always thought to be cleaner and safer to breathe in comparison to the outdoor environment, but in actual reality, indoor air quality is

far more polluted than outdoor air. A report of the World Health Organization (WHO) asserts “the rule of 1000” which states that a pollutant released indoors is one thousand times more likely to reach people’s lungs than a pollutant released outdoor. In our study, we have monitored sick building syndrome marker pollutants (PM10, PM2.5, PM1, Bioaerosols, CO2 and TVOCs) in outdoor and indoor environments in different built-up setting based on three diverse land use configuration (residential, residential cum commercial and commercial) within Delhi university agglomerations. Monitoring sites were selected as per the resident’s demographic settlements based on Delhi government report, for residential site i.e. 1 BHK, 2 BHK and 3 BHK flats, for residential cum commercial i.e. Mixed cluster and for commercial site 2 types of office complex based on space/area/ and diversity of footfalls. To know about the general information, activities, building characteristics, prevalence of sick building syndrome, other respiratory illness, and status of chronic disease among residents, we have performed cross-sectional questionnaire survey and pulmonary function test. Our findings clearly indicated that mixed cluster (MC) and low-income zone (1 BHK) houses (R1) were having the highest pollutant concentration within indoor environment compared to other identified buildings, especially during winter and post-monsoon months. Among seasonal influencing parameters, temperature, humidity, and wind speed play an important role in pollution dispersion in both the indoor and outdoor environment. Temperature shows an inverse moderate correlation with aerosols (particulate matter and bioaerosols) and gaseous pollutants (CO2 and TVOCs) whereas relative humidity does not show any significant correlation with pollutants. The study comprehends that indoor air quality study in urban area is governed by far more complex factors out of which socio-economic stratification that prevails in urban area is most important. Our epidemiological study also stated that building design of housing and economic characteristics have a significant impact on health issues in terms of sick building syndrome & respiratory health. It is high time for the policy makers to take a note of this deteriorating air quality of indoor microenvironments. The study points out the pivotal role of adequate ventilation in improving indoor air quality and thus mitigating indoor air pollution. The practice of timely keeping windows open and using exhaust fans in the house, especially in the kitchen and bathroom, greatly encourages the mixing of indoor, outdoor air and improves the indoor air quality. Interestingly, we have noticed presence of ultrafine PM1 concentration at every monitoring site in both the environment (indoor and outdoor) so formulation of missing National guideline for PM1 concentration is also urgently needed. With the consistent evidence that indoor air pollution and faulty building design increases the risk of sick building syndrome, there is a clear need to make permissible guidelines for SBS marker pollutants so that indoor air quality can be monitored.

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