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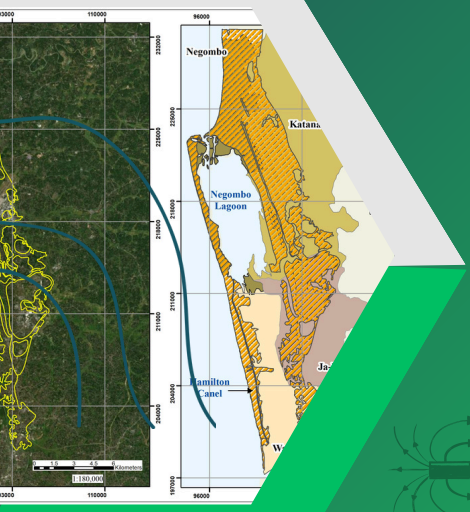
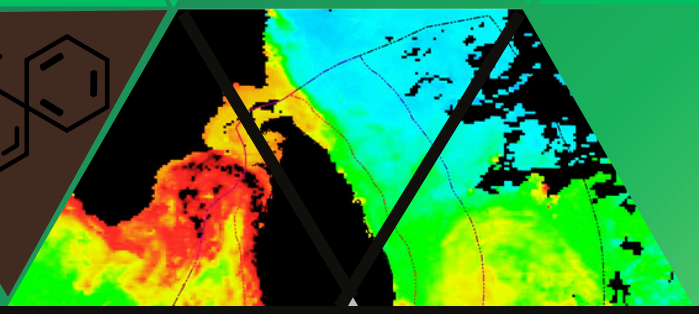
POSTGRADUATE RESEARCH HIGHLIGHTS





PGIS RESCON 2025

Ph.D. Research

M.Phil. Research

M.Sc. Research

VOLUME 10

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MESSAGE FROM THE DIRECTOR

It is with great pride and academic fulfillment that I present the Postgraduate Research Highlights of PGIS 2025, which capture the breadth and depth of postgraduate research across M.Sc., M.Phil., and Ph.D. programmes at the Postgraduate Institute of Science (PGIS), University of Peradeniya. The Postgraduate Research Highlights of PGIS 2025 will be published alongside RESCON 2025, further strengthening the visibility and impact of postgraduate research conducted at the Institute.

Over the years, RESCON has evolved into a premier platform that fosters intellectual exchange, promotes interdisciplinary collaboration, and inspires innovative solutions to challenges of national and global significance. The wide spectrum of research showcased in this volume from advanced computational intelligence, machine learning, and renewable energy technologies to molecular biology, environmental sustainability, plant and zoological sciences, and earth system studies reflects the Institute's unwavering commitment to excellence, relevance, and societal impact.

The diversity of research contributions presented here underscores a defining strength of PGIS: its ability to integrate fundamental scientific inquiry with applied research that addresses contemporary needs. These studies not only advance academic frontiers but also provide valuable insights for sustainable development, public health, natural resource management, and technological innovation.

I extend my sincere appreciation to our postgraduate students and their supervisors for their scholarly rigor, creativity, and perseverance. I also wish to acknowledge the Boards of Study for their continuous guidance, and the Chairperson and Organizing Committee of RESCON 2025 for their dedication and commitment in making this scholarly forum a success.

A special note of appreciation is extended to Dr. Thiloka Ariyasena, Editor-in-Chief; Mr. Prabhath Gunathilake, Managing Editor / PGIS Research Highlights Committee; Dr. Ashwini Amarasinghe, Managing Editor; and the Editorial Committee of the PGIS Research Highlights 2025, for their outstanding efforts in compiling and presenting the diverse research achievements of PGIS.

As PGIS continues to align its research and training with national priorities and global scientific trends, I am confident that the work featured in this volume will serve as a catalyst for future discoveries and innovations, further strengthening our position as a leading centre for postgraduate education and research in Sri Lanka.

Let RESCON 2025 inspire us all to build stronger academic collaborations and to transform scientific knowledge into tangible solutions that benefit our communities, industries, and the environment.

Prof. Nanda Balasooriya
Director, Postgraduate Institute of Science (PGIS)
University of Peradeniya

MESSAGE FROM THE CHAIRPERSON RESCON 2025

It gives me immense pleasure and pride to present the PGIS Research Highlights 2025, published as part of the Postgraduate Institute of Science's (PGIS) mission to enhance research visibility, academic excellence, and industry outreach. This publication brings together a selection of outstanding research discoveries from postgraduate scholars who successfully completed their Ph.D., M.Phil., and M.Sc. degrees in 2024.

Many of these research findings have already appeared in reputable international journals, and several of our scholars have been recognized with prestigious awards for their exceptional contributions to advancing scientific knowledge. The compilation of this volume is a reflection of the dedication, talent, and collaborative spirit of the Research Highlights Committee of RESCON 2025, whose tireless efforts have made this vision a reality.

I extend my heartfelt appreciation to all the postgraduates of the 2024 cohort and their supervisors for their exemplary work, which forms the foundation of this publication. At the most recent convocation, we proudly celebrated the achievements of 301 postgraduates, including 8 Ph.D., 21 M.Phil., and 272 M.Sc./Master's degree recipients each contributing to the vibrant research landscape of the PGIS. Their collective achievements demonstrate the institute's continued commitment to nurturing innovation and excellence across diverse fields of science.

This publication serves not only as a record of scholarly accomplishment but also as an invitation for collaboration, providing a window into the breadth and depth of research carried out at PGIS. Those interested in exploring these topics further are warmly encouraged to connect with the respective authors or their supervisors to foster new academic and industrial partnerships.

I extend my sincere gratitude to the Director of PGIS, Prof. Nanda Balasooriya, for his visionary leadership and unwavering support; to the Editor-in-Chief of Research Highlights of RESCON 2025, Dr. Thiloka Ariyasena for her meticulous editorial guidance; and to the Secretary of RESCON 2025, Dr. Gajaba Ellepola, for his exceptional organizational contribution. My appreciation also goes to the Editorial Committee of the RESCON Research Highlights 2025 for their dedicated and efficient efforts in bringing this publication to life.

Finally, I wish the RESCON 2025 team every success in conducting yet another impactful conference that continues to inspire scientific dialogue, innovation, and collaboration.

Prof. Manawadevi Y.U. Ganehenege
Chairperson
RESCON 2025 & Board of Study in Chemical Sciences
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University of Peradeniya

MESSAGE FROM THE EDITOR-IN-CHIEF

It is with great pleasure that I present the Postgraduate Research Highlights, Volume 10 in parallel to the annual research congress RESCON 2025 of Postgraduate Institute of Science, University of Peradeniya. Postgraduate Research Highlights 2025 is a compilation of selected research works by Ph.D., M.Phil. and M.Sc. (SLQF Level 10) graduates of the Postgraduate Institute of Science who earned their degrees in 2024.

The theme of RESCON 2025, 'Synergy in Science: Uniting Disciplines for a Better Tomorrow' offers a compelling vision for the future. Volume 10, presented herein, reflects the commitment of Postgraduate Institute of Science to advancing high-quality, multidisciplinary research that addresses real-world challenges and contribute to national development. The studies featured in this volume exemplify the multidisciplinary collaborations ranging from physical sciences, environmental and earth sciences, life sciences, health sciences, data sciences, mathematics and science education. Collectively, they demonstrate that innovation emerges when diverse minds and methods intersect.

As the editor-in-chief of Postgraduate Research Highlights 2025, I congratulate all the authors who contributed their research articles. I'm also grateful to their research supervisors, whose guidance has been the foundation for their success. My gratitude also goes to the editorial board of Postgraduate Research Highlights 2025 for their tireless efforts in reviewing the articles and compiling the volume.

I would like to express my sincere gratitude to the Director/PGIS, Prof. Nanda Balasooriya, and the Chairperson/RESCON 2025, Prof. Manawadevi Y.U. Ganehenege, for their continued support and encouragement. My sincere appreciation also goes to the organizing committee of RESCON 2025 for their support in bringing this intellectual forum to completion.

May Postgraduate Research Highlights 2025 continue to inspire our graduates to pursue their research passions, contributing to the advancement of science in Sri Lanka and beyond.

Dr. J.A.Thiloka C. Ariyasena
Editor-in-Chief
PGIS Research Highlights 2025
Postgraduate Institute of Science
University of Peradeniya

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GREEN TEMPLATE-MEDIATED SYNTHESIS AND CHARACTERIZATION OF HYDROXYAPATITE NANOPARTICLES UTILIZING BANANA PEEL FOR LEAD(II) REMOVAL FROM AQUEOUS SOLUTIONS

K.M.S.M. Keerthisinghe *graduated in 2019 with a B.Sc. degree in Biological Science from Eastern University, Sri Lanka. In 2025, she completed her M.Sc. in Analytical Chemistry at the Postgraduate Institute of Science (PGIS), University of Peradeniya, Sri Lanka. Her research focuses on the sustainable synthesis of nanomaterials for various applications, including advanced environmental remediation. With a strong interest in advanced materials development, she is currently focusing on polymer and nano-material synthesis, aiming to contribute to the development of next-generation functional materials.*

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Water is essential for all living organisms and plays a critical role in sustaining biodiversity and supporting human health. However, access to clean and safe water is increasingly threatened by both natural and anthropogenic sources of pollution. These pollutants broadly include inorganic metal ions, synthetic organic compounds such as herbicides and insecticides, polyaromatic hydrocarbons, and excess nutrients such as phosphates and nitrates. Among these, heavy metals are of particular concern due to their toxicity, persistence, and bioaccumulation potential across the food chain, posing severe risks to human health, animals, and the broader ecosystem.

Lead (Pb), in particular, is one of the most toxic and frequently detected metals in industrial effluents, especially from battery manufacturing, metal plating, mining, and the paint and ceramics industries. The presence of Pb in water bodies leads to detrimental health outcomes including neurological impairments, reproductive disorders, chromosomal aberrations, hypertension, miscarriages, and many other systemic toxicities. Due to these severe effects, effective removal strategies for Lead(II) from contaminated water are critical.

To address heavy metal contamination, various conventional water treatment methods, such as chemical precipitation, ion exchange, membrane filtration and electrochemical treatment, have

been employed. Despite their effectiveness, these techniques often involve high operational cost, generate secondary pollutants such as sludge, and may struggle to remove trace metal concentrations efficiently. In contrast, adsorption has emerged as a promising alternative due to its simplicity, cost-effectiveness, and ability to remove even low concentrations of heavy metals from wastewater. The development of novel adsorbents with high selectivity, enhanced adsorption capacity and improved efficiency in handling various contaminants over a wide range of pH levels and initial adsorbate concentration is essential for the continued development of adsorption technology. Activated carbon, activated clay, zeolites, diatomaceous earth, and polymeric materials are the most common materials used as adsorbents; however, their applicability is limited due to low efficiency and technical and separation problems. Among various adsorbents, synthetic hydroxyapatite is a promising adsorbent because of its high affinity for heavy metals, their chemical similarity to human bone and teeth, low water solubility, and absence of secondary pollutants.

Hydroxyapatite, a calcium phosphate compound, has attracted attention for both biomedical and environmental applications due to its favorable physicochemical and biological properties (Figure 1). Hydroxyapatite is the primary constituent within the mineral composition of bones and teeth, representing a mineral variant of natural calcium apatite, with the chemical formula $Ca_{10}(PO_4)_6(OH)_2$. It is a crystalline substance with a polar hexagonal structure and substantial anisotropy that tends to create a one-dimensional nanostructure with a greater surface area. The unit cell dimension of hydroxyapatite is estimated as a = 9.37 Å and c = 6.88 Å and a P63/m space group. While hydroxyapatite is widely used in medical fields for coating implants, drug delivery, and tissue engineering, it has also proven effective in environmental remediation. It serves as an adsorbent for removing dyes, heavy metals, and other emerging contaminants. One of the most efficient treatment techniques for pollution management is ion exchange. The exceptional flexibility and stability of the apatitic structure allow for a wide range of cationic and anionic substitutions. Its ability to incorporate ionic substitutions allows hydroxyapatite to adsorb a range of heavy metals and pollutants from water. The adsorption efficiency of hydroxyapatite can be significantly enhanced by reducing it to the nanoscale. Synthesis of nanoscale hydroxyapatite further enhances surface area and reactive sites, thereby improving adsorption efficiency. However, nanoparticle synthesis commonly requires chemical surfactants or templates, which pose environmental concerns.

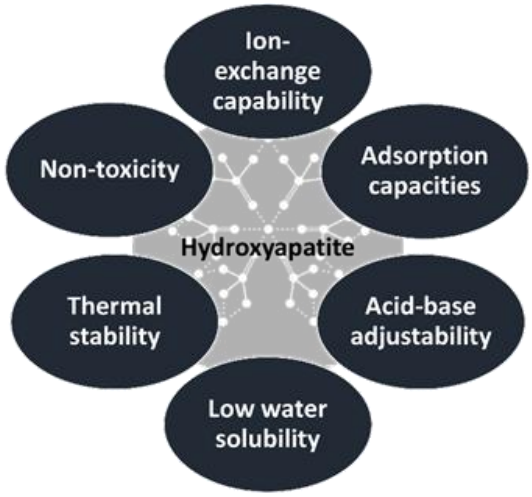

Figure 1. Properties of hydroxyapatite

This study aimed to synthesize hydroxyapatite nanoparticles through a green, template-mediated method using banana peel as a natural surfactant. Banana peel, an abundant agricultural waste, not only acts as a capping and templating agent in nanoparticle synthesis but also offers a sustainable and cost-effective route for producing functional materials.

Methodology

This study explores an environmentally benign synthesis route for hydroxyapatite nanoparticles using banana peel as a green surfactant template. Banana peels are rich in natural polymers, such as pectin, lignin, cellulose with functional groups (e.g. carboxyl, hydroxyl and amine), that can interact with metal ions. The green synthesis involves preparing banana peel powder, blending it with $Ca(OH)_2$, and incorporating KH_2PO_4 under controlled conditions. The mixture is

subjected to drying, washing, filtration, and calcination. This template not only controls nucleation and particle morphology but also utilizes a low-cost, sustainable waste resource. The synthesis mechanism was optimized by varying the banana peel concentration, banana peel powder and extract concentration, and the surfactant addition into the precursor.

The synthesized hydroxyapatite nanoparticles were characterized using Fourier transform infrared spectroscopy (FTIR), powder X-ray diffraction (PXRD), scanning electron microscopy (SEM), and thermal gravimetric analysis (TGA). The incorporation of banana peel as a green template and surfactant in the synthesis of hydroxyapatite nanoparticles generally leads to a reduction in particle size and promotes a more uniform and homogeneous morphology.

Results and Discussion

According to the results obtained, the banana peel acts as a bio-template primarily through its carboxylate groups, which chelate with Ca^{2+} ions, controlling nucleation and directionality of hydroxyapatite crystal growth. This restricts particle growth along certain axes, leading to the formation of homogeneously sized nanoparticles. During washing, residual banana components are mostly removed, leaving behind structured hydroxyapatite with increased surface energy and improved adsorption capacity for metal ions. This method exemplifies waste valorization, transforming waste into valuable materials for environmental applications.

The synthesized banana peel incorporated hydroxyapatite was evaluated for Pb(II) adsorption performance over a range of pH values to reflect typical industrial wastewater conditions. The hydroxyapatite nanoparticles synthesized with banana peel outperformed both hydroxyapatite (without green template) and raw banana peel in Pb(II) removal across different initial concentrations and doses. Notably, they showed particularly high efficiency under acidic conditions, aligning with industrial effluents that are often acidic. Removal is attributed to both dissolution-precipitation (lead-phosphate precipitation at low pH) and ion-exchange processes (substitution of Ca^{2+} with Pb^{2+} within the hydroxyapatite lattice at near-neutral pH). The increased surface area provided by working banana peel as a surfactant enhances the removal percentage. Kinetics studies revealed that the pseudo-second-order model best described the adsorption behavior, indicating that chemisorption is the dominant mechanism. Comparative analysis between banana peel alone, pure hydroxyapatite, and hydroxyapatite nanoparticles synthesized using banana peel showed that the hydroxyapatite synthesized using banana peel outperformed the individual components, reinforcing the synergistic effect of the green synthesis approach.

Conclusion

This investigation demonstrates that banana peel, an abundant biological waste, can serve as an effective green template for synthesizing high-performance hydroxyapatite nanoparticles. The resulting hydroxyapatite nanoparticles synthesized using banana peel offer significant advantages: enhanced morphology, increased surface area, greater crystallinity, and remarkable Pb(II) adsorption efficiency, especially under acidic conditions. The adsorption process is dominated by chemisorption rather than simple diffusion, ensuring robustness and stability in environmental remediation. This green method not only valorizes agricultural waste but also presents an effective, scalable, and cost-efficient strategy for heavy metal removal from wastewater, with strong potential for extension to other pollutants and large-scale applications. Further research is warranted to explore its applicability to a broader range of contaminants.

Acknowledgment

The author is grateful for the support offered by the Department of Chemistry, University of Peradeniya, Sri Lanka and Postgraduate Institute of Science University of Peradeniya, Sri Lanka for facilitating the flexible learning environment by providing the necessary laboratory facilities with chemicals and instruments.

Selected References

Afolabi, F. O., Musonge, P., & Bakare, B. F. (2021). *Evaluation of lead (II) removal from wastewater using banana peels: Optimization study. Polish Journal of Environmental Studies*, 30(2), 1487–1496. https://doi.org/10.15244/pjoes/122449

Alorku, K., Manoj, M., & Yuan, A. (2020). *A plant-mediated synthesis of nanostructured hydroxyapatite for biomedical applications: A review. RSC Advances*, 10(69), 40923–40939. https://doi.org/10.1039/d0ra08529d

Collins Arun Prakash, V., Venda, I., & Thamizharasi, V. (2021). *Synthesis and characterization of surfactant-assisted hydroxyapatite powder using microemulsion method. Materials Today: Proceedings*, 51, 1788–1792. https://doi.org/10.1016/j.matpr.2021.05.059

El Hammari, L., Hamed, R., Azzaoui, K., Jodeh, S., & Lati, S. (2023). *Optimization of the adsorption of lead (II) by hydroxyapatite using a factorial design: Density functional theory and molecular dynamics. Frontiers in Environmental Science*, 11, 1112019. https://doi.org/10.3389/fenvs.2023.1112019

Foroughi, M. R., & Zarei, M. (2015). *Synthesis of hydroxyapatite nanoparticles for the removal of Pb(II) and Cd(II) from industrial wastewaters. Research on Chemical Intermediates*, 41(6), 4009–4019. https://doi.org/10.1007/s11164-013-1506-4

GA, A. B. (2020). *Hydroxyapatite-based materials for heavy metal removal in wastewater treatment. Petroleum and Petrochemical Engineering Journal*, 4(1), 1–5. https://doi.org/10.23880/ppej-16000227

Ganta, D. D., Hirpaye, B. Y., Raghavanpillai, S. K., & Menber, S. Y. (2022). *Green synthesis of hydroxyapatite nanoparticles using Monoon longifolium leaf extract for removal of fluoride from aqueous solution. Journal of Chemistry*, 2022, Article 4917604. https://doi.org/10.1155/2022/4917604

Gopi, D., Kavitha, L., & Rajeswari, D. (2015). *Synthesis of pure and substituted hydroxyapatite nanoparticles by cost effective facile methods.* In *Handbook of Nanoparticles* (pp. 1–1426). Springer. https://doi.org/10.1007/978-3-319-15338-4

Ibrahim, M., Labaki, M., Giraudon, J.-M., & Lamonier, J.-F. (2020). *Hydroxyapatite, a multifunctional material for air, water and soil pollution control: A review. Journal of Hazardous Materials*, 383, 121139. https://doi.org/10.1016/j.jhazmat.2019.121139

Kumar, G. S., Rajendran, S., Karthi, S., Govindan, R., Girija, E. K., Karunakaran, G., et al. (2017). *Green synthesis and antibacterial activity of hydroxyapatite nanorods for orthopedic applications. MRS Communications*, 7(2), 183–188. https://doi.org/10.1557/mrc.2017.18

Mohamed, R. M., Hashim, N., Abdullah, S., Abdullah, N., Mohamed, A., Asshaary Daud, M. A., et al. (2020). *Adsorption of heavy metals on banana peel bioadsorbent. Journal of Physics: Conference Series*, 1532(1), 012014. https://doi.org/10.1088/1742-6596/1532/1/012014

Nayak, A., & Bhushan, B. (2021). *Hydroxyapatite as an advanced adsorbent for removal of heavy metal ions from water: Focus on its applications and limitations. Materials Today: Proceedings*, 46, 11029–11034. https://doi.org/10.1016/j.matpr.2021.02.149

Pai, S. M., Kini, S., Selvaraj, R., & Pugazhendhi, A. (2020). *A review on the synthesis of hydroxyapatite, its composites and adsorptive removal of pollutants from wastewater. Journal of Water Process Engineering*, 38, 101574. https://doi.org/10.1016/j.jwpe.2020.101574

Prasad, P. S., Marupalli, B. C. G., Das, S., & Das, K. (2023). *Surfactant-assisted synthesis of hydroxyapatite particles: A comprehensive review. Journal of Materials Science*, 58(16), 6076–6105. https://doi.org/10.1007/s10853-023-08366-x

Safatian, F., Doago, Z., Torabbeigi, M., Rahmani Shams, H., & Ahadi, N. (2019). *Lead ion removal from water by hydroxyapatite nanostructures synthesized from egg shells with microwave irradiation. Applied Water Science*, 9(1), 1–6. https://doi.org/10.1007/s13201-019-0979-8

Tp, G., Um, R., & Rmg, R. (2018). *Facile synthesis of hydroxyapatite nanoparticles by a polymer-assisted method: Morphology, mechanical properties, and formation mechanism. Journal of Clinical Investigative Studies*, 2018, 1–6. https://doi.org/10.15761/JCIS.1000101

Varadarajan, V., Varsha, M., Vijayasekaran, K., & Shankar, S. V. (2020). *Comparative studies of hydroxyapatite (HAp) nanoparticles synthesized by using different green templates. AIP Conference Proceedings*, 2240, Article 050004. https://doi.org/10.1063/5.0011048

Zhu, K., Yanagisawa, K., Shimanouchi, R., Onda, A., & Kajiyoshi, K. (2006). *Preferential occupancy of metal ions in the hydroxyapatite solid solutions synthesized by hydrothermal method. Journal of the European Ceramic Society*, 26(4–5), 509–513. https://doi.org/10.1016/j.jeurceramsoc.2005.07.019

Publications

Keerthisinghe, S. M., Gamagedara, T. P., & Priyantha, N. (2024). *Biosorption of lead(II) from aqueous solution by banana peel: Optimization and adsorption isotherm study.* In *Second International Conference on Frontiers in Chemical Technology*, Institute of Chemistry Ceylon, 20th–22nd June 2024 (p. 56).

Keerthisinghe, S. M., Gamagedara, T. P., Jeewantha, J., & Priyantha, N. (2025). *A review on green hydroxyapatite nanoparticles and composites for sustainable pollutant removal. Comments in Inorganic Chemistry.* Under review.

Keerthisinghe, S. M., Gamagedara, T. P., & Priyantha, N. (2024). *Green-template mediated synthesis of hydroxyapatite nanoparticles utilizing banana peel for Pb(II) removal from aqueous solution.* https://doi.org/10.2139/ssrn.5076418

Keerthisinghe, S. M., Gamagedara, T. P., & Priyantha, N. (2024). *Green synthesis, characterization, and pH-dependent adsorption of lead(II) by hydroxyapatite nanoparticles.* In *Proceedings of the Postgraduate Institute of Science Research Congress*, University of Peradeniya, 1st–2nd November 2024 (p. 32).

Keerthisinghe, S. M., Gamagedara, T. P., & Priyantha, N. (2025). *Intra-particle diffusion, isotherm and kinetics study of enhanced Pb(II) removal on acid-treated banana (Musa x paradisiaca) peel. Next Materials.* Under review.

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RISK ASSESSMENT OF BIOCHAR INCORPORATION AND EFFECT OF SORPTION AND DESORPTION OF FOUR TRACE METALS ON BIOCHAR MIXED COCONUT GROWING SOIL SYSTEMS

M.K.F. Nadheesha *graduated in 2000 with a B.Sc. Special Degree in Chemistry with Second Class (Upper Division) from University of Sri Jayewardenepura and immediately embarked on a Master's programme in Food Science and Technology in the same university. Thereafter, Nadheesha joined the research staff of Coconut Research Institute. Later, she earned another Master's Degree in Chemistry from Eastern Illinois University, USA. Nadheesha obtained her Ph.D. Degree in 2025 from the PGIS.*

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This is an environmental concerned research project of which negative and positive aspects of both heavy metals and biochar amendment to soil have been considered, where coconut growing soil is a major concern.

Coconut palm (*Cocos nucifera*), one of the three main plantation crops in Sri Lanka, has a life span of more than 60 years. In Sri Lanka, the palm is distributed in the entire country covering an extent of 443,538 ha (2014 Statistics), except more than 900 m elevation from sea level. However, it grows profusely in the 'coconut triangle' covering the districts Kurunegala, Puttlalam and Gampaha. At present, coconut contributes 1.0% to the Gross Domestic Production of Sri Lanka. The annual revenue from the export of kernel and non-kernel coconut products was amounted to Rs. 94.72 billion in 2018 which accounted to US $ 0.583 million to the national income. Coconut is also a significant component in the daily diet of Sri Lankans. The growth and the yield of coconuts are directly influenced by climatic variability (temperature and rainfall) and soil suitability. The current annual coconut production of the country is approximately 2,800 million nuts; but the current demand is 3,600 million nuts per annum. To meet the current demand, improvement of soil fertility is one of the strategies. Biochar, a soil conditioner incorporated into soil to enhance the soil quality, acts as a sustainable carbon source for the coconut growing soil. In addition, continuous application of fertilizer in the form of chemical and mineral together or organic are recommended yearly through which nutrients, N, P, K and Mg sources are applied to soil. Usually, the P source is in the form of rock phosphates. Parent material of rock phosphates contains toxic Cd trace metal which is thus present in the P source. Consequently, Cd accumulates in soil, and coconut palm uptakes Cd from soil.

Biochar is derived from carbonaceous material through pyrolysis, which is a process in which organic material is chemically decomposed at elevated temperatures in the absence of oxygen. This process typically occurs at high temperatures above 350 °C and under pressure. Biochar could be made from any source material or feedstock having a high carbon content. During pyrolysis, various carbon-compounds in the feed stock are converted to persistent (stable) and labile (unstable) fractions in the final biochar product. The stable carbon compounds, primarily aromatic ring structures are likely to remain in soil for hundreds, and even thousands of years. Therefore, biochar remains in coconut growing soil while improving soil quality and thereby improving the productivity of coconut palm during its life span.

Although positive and negative aspects of both heavy metals and biochar amendment to soil have been considered for the PhD research project, this write up aims at two possible types of risk assessments: one risk assessment is polycyclic aromatic hydrocarbons (PAHs) in coconut plantation after long term application of biochar; the second type of risk assessment is assessment of potential release of Cd in biochar incorporated soil.

It is inherent in generating PAHs during pyrolysis of biochar production. Organic compounds present in the biomass decompose into smaller, unstable fragments, which contain highly reactive free radicals. Therefore, they recombine to form graphene arrangement of PAHs and cluster arrangement having more than two fused rings with different forms, such as linear bent and cluster.

The name for PAHs is common for fused aromatic structures where two or more ring components are fused in a manner that two or more carbons of one ring component are shared with other ring components in an aromatic system. They are thus called polycyclic aromatic hydrocarbons which are also called by other names: polycyclic organic matter (POM), polynuclear aromatic hydrocarbons, polynuclear aromatics (PNAs), polynuclear hydrocarbons and polarenes. Some examples are given in Figure 1.

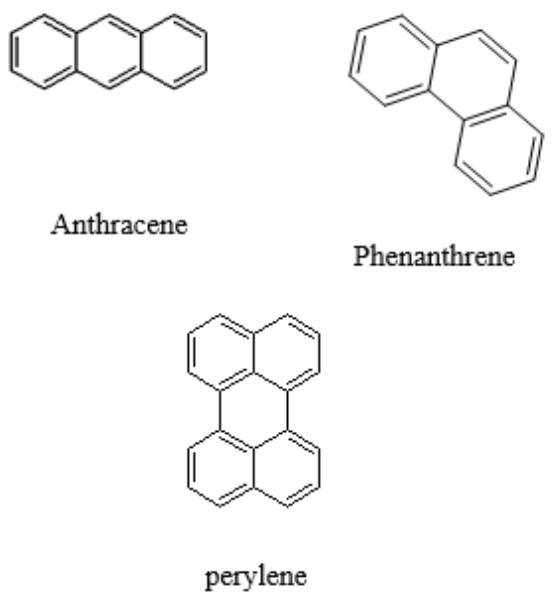


Figure 1. Different types of PAHs

Incomplete combustion, either natural or anthropogenic mode, has been identified as the single largest contributor of PAHs to the environment. Generally, PAHs generate as a mixture of different PAHs. At present, they are of particular concern due to their specific properties, such as hydrophobicity, recalcitrance, persistence, potential carcinogenic, mutagenic, and toxic to living beings. However, 16 PAHs, namely naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a] pyrene, dibenz[a,h]anthracene, benzo[ghi]perylene and indeno[1,2,3-cd] pyrene], have been declared as harmful to human and animals by environmental protective agencies. Therefore, 16 aforementioned PAHs of soil, leaf, root, and kernel samples of biochar incorporated coconut site were assessed.

Methodology

This research is conducted in two directions. First direction is organic toxicant PAH assessment of biochar incorporated soil in comparison with general fertilizer application. Second direction is

trace metallic toxicant assessment Cd sorption and desorption with soil and (soil + biochar).

Ten coconut palms in the field were randomly chosen for each treatment: (Treatment 1) control with usual current recommended chemical/mineral fertilizer (CRCF) applied palms continually (Treatment 2) coconut shell biochar (40 kg) and poultry manure (60 kg) were incorporated once a year for a period of four consecutive years from 2008 to 2012, and later on continuation with CRCF which was operated once a year with the following fertilizer doses: urea (800 g), muriate of potash (MOP) (1.600 kg), Eppawala rock phosphate (ERP) (900 g) and dolomite (1.000 kg). Leaf samples were collected from the 14th frond of which the middle area of middle leaflets were chosen to cut from randomly chosen ten plants for each treatment. Root samples were collected at the depth of 20-40 cm of each palm in the middle of manure circle (MC) which is an area of 1.75 m diameter. One nut was chosen randomly from each palm from a pick. The kernel was shredded and representative samples were taken.

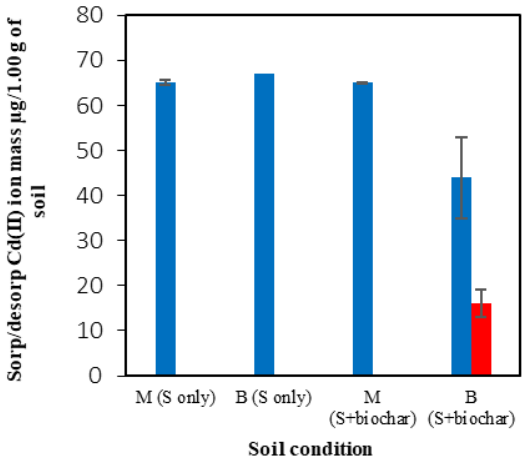
Samples were prepared separately, microwave digested (three surrogated standards were added to the samples before extraction), and the extracts were cleaned using columns separately, and finally, analyzed for PAHs using GC-MS. The methods of abovementioned steps were illustrated under the sections of 3.2 of chapter 3 of the thesis.

Experiments were carried out for two types of soil series namely Madampe soil series (M): Sandy loam and Boralu soil series (B): sandy clay loam, which is the moderately suitable soil of coconut growing soil classification. Firstly, shaking time, settling time, soil mass, initial Cd concentration was optimized under laboratory conditions for each soil series. A laboratory batch experiments having six replicates were conducted using both soil series; Each soil type (3.00 g) was shaken with 40.00 mL of 10 mg L^{-1} Cd(II) solution in 0.010 mol L^{-1} KNO_3 solution and further inclusion of 100 mg L^{-1} of Cu(II), Mn(II) and Zn(II) each ion to represent ionic medium in soil and other competitive ions in soil, respectively. Desorption experiments were conducted with 1.00 g of soil and 20.00 mL of 0.010 mol L^{-1} KNO_3 solution.

Results and Discussion

Samples from soil, root, leaf and kernel were carefully examined using GC-MS for 16 PAHs and compared with standards. It was found that only naphthalene was present in leaf extracts of biochar treated palms. In addition, peaks of initially added surrogated standards, chrysene (D12) and benzo(a)pyrene (D7) have disappeared in all chromatograms while the peak of anthracene (D10) has appeared only in a few chromatograms with decreased peak intensity.

Figure 2 reveals that the extent of Cd(II) sorption on soil under four soil conditions is higher than that of desorption. Moreover, Cd(II) sorption on B with biochar is lower and the extent of desorption is higher in comparison with other three soil conditions. Higher Cd(II) desorption is an indication of binding on exchangeable sites of soil and biochar and exchange with soil solution. Hence, there is a potential in up taking more Cd by the coconut palm. M is marine deposit soil, containing metal oxides mainly so that trace metals in soil specifically bind with metal oxides and desorption is irreversible. However, the presence of biochar Cd could bind to cation exchangeable sites nonspecifically. Nonspecifically bound Cd could easily release to the soil solution. B is degraded soil with high ion oxides, clay, and organic carbon (OC). Cation exchange sites are present in clay, OC, and biochar. As Cd(II) has affinity toward cation exchange sites, this study concludes that soil itself reduces the movement of Cd(II) when present in minute levels but in the presence of biochar, it is possible to bind Cd(II) on ion exchange sites demonstrating potential in releasing to the soil system. This leads Cd movement in soil as well as plant uptake in the environment.



******S* *denotes soil.*

Figure 2. Sorption (▪) and desorption (▪) of Cd(II) on M soil series and B soil series with biochar derived at 500 ^{0}C (S+ biochar) and without biochar (S only), conditions: pH range 5-7, shaking time and settling time for M: 3.0 h and 30 min B: 6.0 h and 50 min, respectively.

Conclusion

Hence, this research focus concluded that extraction, purification and isolation processes of PAH are to be further refined to achieve the surrogated PAHs to appear on chromatograms. Then it can be interpreted to reach conclusions on the presence or the absence of PAHs in different sources tested. However, it has been proven in the literature that the presence of some of the PAHs from the 16 PAHs mentioned above, and all deuterated standards were present in the same chromatogram of biochar derived samples such as manure, weed, rice husk and residues of maize. It is recorded that the maximum acceptable limit of PAHs in biochar has to be 16 µg g^{-1} to be sold. Furthermore, the human risk of soil contaminated with PAHs has also been postulated. Furthermore, there were proposed mechanisms in generating PAHs with the thermal treatment of feed stock as well.

Acknowledgment

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Selected References

Abdel-Shafy, H. I., & Mansour, M. S. M. (2016). *A review on polycyclic aromatic hydrocarbons: Source, environmental impact, effect on human health and remediation. Egyptian Journal of Petroleum*, 25(1), 107–123. https://doi.org/10.1016/j.ejpe.2015.03.011

Dai, Z., Meng, J., Muhammed, N., Liu, X., Wan, H., He, Y., Brookes, P., & Xu, J. (2013). *The potential feasibility for soil improvement, based on the properties of biochars pyrolyzed from different feedstocks. Journal of Soils and Sediments*, 13(6), 989–1000. https://doi.org/10.1007/s11368-013-0681-8

Department of Sensus and Statistics. (2014). *[PDF document]*. Retrieved from http://repositorio.unan.edu.ni/2986/1/5624.pdf

Hale, S. E., Lehmann, J., Rutherford, D., Zimmerman, A. R., Bachmann, R. T., Shitumbanuma, V., Tool, A. O., Sundqvist, K. L., H. P. H., & Cornelissen, A. G. (2012). *Quantifying the total and bioavailable polycyclic aromatic hydrocarbons and dioxins in biochars. Environmental Science & Technology*, 46(5), 2830–2838. https://doi.org/10.1021/es204125z

Khalid, F. N. M., & Klarup, D. (2015). *The influence of sunlight and oxidative treatment on measured PAH concentrations in biochar. Environmental Science and Pollution Research International*, 22(17), 12975–12981. https://doi.org/10.1007/s11356-015-4590-4

Nadheesha, M. K. F., Mohotti, A. J., & Priyantha, N. (2021). *Cadmium uptake by coconut palm and its sorption on soil in ionic medium. International Journal of Agriculture, Forestry and Plantation*, 11, 63–70.

Nadheesha, M. K. F., Priyantha, N., & Mohotti, J. (2022, July). *Effect of biochar on sorption and desorption characteristics of cadmium ion on two types of coconut growing soil series* [Paper presentation]. *5th World Agroforestry Conference*, Canada.

Verheijen, F. G. A., Jeffery, S., Bastos, A. C., van der Velde, M., & Diafas, I. (2009). *Biochar application to soils: A critical scientific review of effects on soil properties, processes and functions (EUR 24099 EN).* Luxembourg: Office for the Official Publications of the European Communities.

Publications

Nadheesha, M. K. F., Gunasekara, T. H. U. D. S., Priyantha, N., & Wickramasinghe, A. (2017). *Uptake of micronutrients by coconut palm under two different fertilizer practices.* In *Proceedings of PGIS Research Congress*, University of Peradeniya, 08–09 September.

Nadheesha, M. K. F., Mohotti, A. J., & Priyantha, N. (2020). *Sorption isotherm analysis of sandy texture soil: Madampe coconut growing soil.* In *Proceedings of Annual Congress of the Postgraduate Institute of Agriculture (PGIA)*, University of Peradeniya, p. 42.

Nadheesha, M. K. F., Mohotti, A. J., & Priyantha, N. (2021). *Cadmium uptake by coconut palm and its sorption on soil in ionic medium. International Journal of Agriculture and Plant Science*, 11, 63–70.

Nadheesha, M. K. F., Mohotti, A. J., & Priyantha, N. (2021). *Cadmium uptake by coconut palm and its sorption on soil in ionic medium.* In *Second International Plantation Conference*, Malaysia, p. 24.

Nadheesha, M. K. F., Mohotti, A. J., & Priyantha, N. (2021). *Sorption isotherm analysis of trace metals on a sandy textured coconut growing soil. Tropical Agricultural Research*, 32(3), 63–70.

Nadheesha, M. K. F., Priyantha, N., & Mohotti, J. (2022). *Effect of biochar on sorption and desorption characteristics of cadmium ion on two types of coconut growing soil series.* In *5th World Agroforestry Conference*, Canada.

Nadheesha, M. K. F., Priyantha, N., Mohotti, A. J., & Kurundukubura, C. (2016). *Comparison of cadmium sorption in ionic and nonionic media on coconut growing soil.* In *Proceedings of PGIS Research Congress*, University of Peradeniya, p. 17.

Thesis reference

Nadheesha, M.K.F. (2025). Risk Assessment of Biochar Incorporation and Effect of Sorption and Desorption of Four Trace Metals on Biochar Mixed Coconut Growing Soil Systems. PhD Thesis Post Graduate Institute of Science. PP 100-101, 69-72.

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AN ASSESSMENT OF GROUNDWATER RECHARGE POTENTIAL IN THE THANAMALVILA DIVISIONAL SECRETARIAT DIVISION, UVA PROVINCE, SRI LANKA

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Water is a vital natural resource essential for food security, public health, and environmental sustainability. However, only 3% of the Earth's total water volume is suitable for human consumption, and approximately 30% of that exists as groundwater. Globally, over 2 billion people depend on groundwater for drinking, which also supports 40% of agricultural irrigation needs. Unfortunately, the rate of groundwater extraction has outpaced the natural replenishment of aquifers, leading to depletion in many regions. Alongside rapid population growth and accelerating climate change, water scarcity is becoming an increasingly critical issue. Changes in rainfall patterns, rising temperatures, sea-level rise, and environmental degradation further diminish the availability of renewable freshwater, particularly affecting developing countries where access to clean water poses a major public health and economic challenge. Consequently, effective groundwater management has emerged as an urgent global concern.

In this context, artificial groundwater recharge facilitates the infiltration of surface water into aquifers. The success of this strategy depends on various physical factors, including topography, soil type, slope, land use, rainfall, and drainage patterns, all of which influence the potential for recharge. Thus, identifying suitable recharge zones requires the integration of multiple spatial variables and an understanding of their hydrological interactions. Geospatial technologies such as Geographic Information Systems (GIS) and remote sensing are powerful tools for mapping and analyzing groundwater recharge potential. By combining various surface features like terrain, vegetation, and hydrology, these technologies can assess infiltration capacity and water flow pathways. Identifying groundwater recharge zones using GIS-based approaches is essential for planning sustainable water resource management in vulnerable regions.

Sri Lanka, as a developing country, is also grappling with water scarcity and limited access to safe drinking water, especially in the dry zone. This region receives less than 1750 mm of rainfall annually while supporting large populations and agricultural activities. However, increasing development and population pressures have exacerbated water scarcity. The study area, the Thanamalvila Divisional Secretariat Division (DSD), is located in the dry zone and relies heavily on groundwater for drinking and agriculture. Yet, it faces significant challenges due to declining groundwater quality and overuse from intensive agricultural practices. Despite this need, limited research has been conducted to identify suitable areas for artificial recharge. This study aimed to address this gap by employing GIS, hydrological modeling, and groundwater assessments to locate and prioritize recharge zones, thereby laying the foundation for sustainable water management in the region.

The primary objective of the study was to identify potential groundwater recharge zones utilizing GIS and hydrological models, taking into account geomorphological features and rainfall data. The specific goals included: Identifying areas suitable for groundwater recharge based on geomorphological, geological, and rainfall data, determining the most suitable locations for groundwater recharge that pose minimal pollution risk to the groundwater, and establishing a safe water extraction rate to effectively manage groundwater recharge volumes.

Methodology

The secondary data were utilized to identify the geomorphological features, soil types, and rainfall patterns of the Thanamalvila area, specifically within its DSD boundary. Additionally, land use and land cover data were collected from Landsat images and topographical maps. These features, including geology, land use and land cover, slope, drainage network, rainfall, and soil type, were considered as thematic layers to assess potential groundwater recharge using the ArcGIS 10.4 platform.

Geological data were obtained from the Geological Survey and Mines Bureau (GSMB) to develop the weak zone map for the Thanamalvila DSD. The Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Built-up Index (NDBI) maps were developed utilizing the Landsat 8 satellite data of the United States Geological Survey (USGS). A contour map was created using Google Earth Pro, USGS data, and ArcGIS software, which was subsequently used to generate the slope map for the Thanamalvila DSD. The stream network contributed to the development of the drainage network map, while the rainfall map was constructed using average annual rainfall data collected from approximately 20 rain gauge stations.

A weighted overlay analysis was conducted to create a map indicating suitable areas for groundwater recharge potential in the Thanamalvila DSD. Weights were assigned based on the suitability of each geospatial factor, using scales ranging from 1 to 5, 1 to 9, or other values. Map layers such as weak zones, elevation, and soil cover received high weights due to their significant contribution to groundwater recharge. Additionally, separate weight values were assigned to the rainfall, drainage network, and land use maps.

Results and Discussion

The potential groundwater recharging zones for the study area were classified into five categories. According to the findings, the Thanamalvila area displayed a moderate potential for groundwater recharge. The highest recharging potential was observed in Hambegamuwa GND, whereas the lowest recharging potential was found in Kandiyapitawewa GND and Maha Wewa areas. Parts of Sooriyaara GND, Usgala GND, and Bodagama GND also demonstrated good potential for groundwater recharge (Fig. 1).

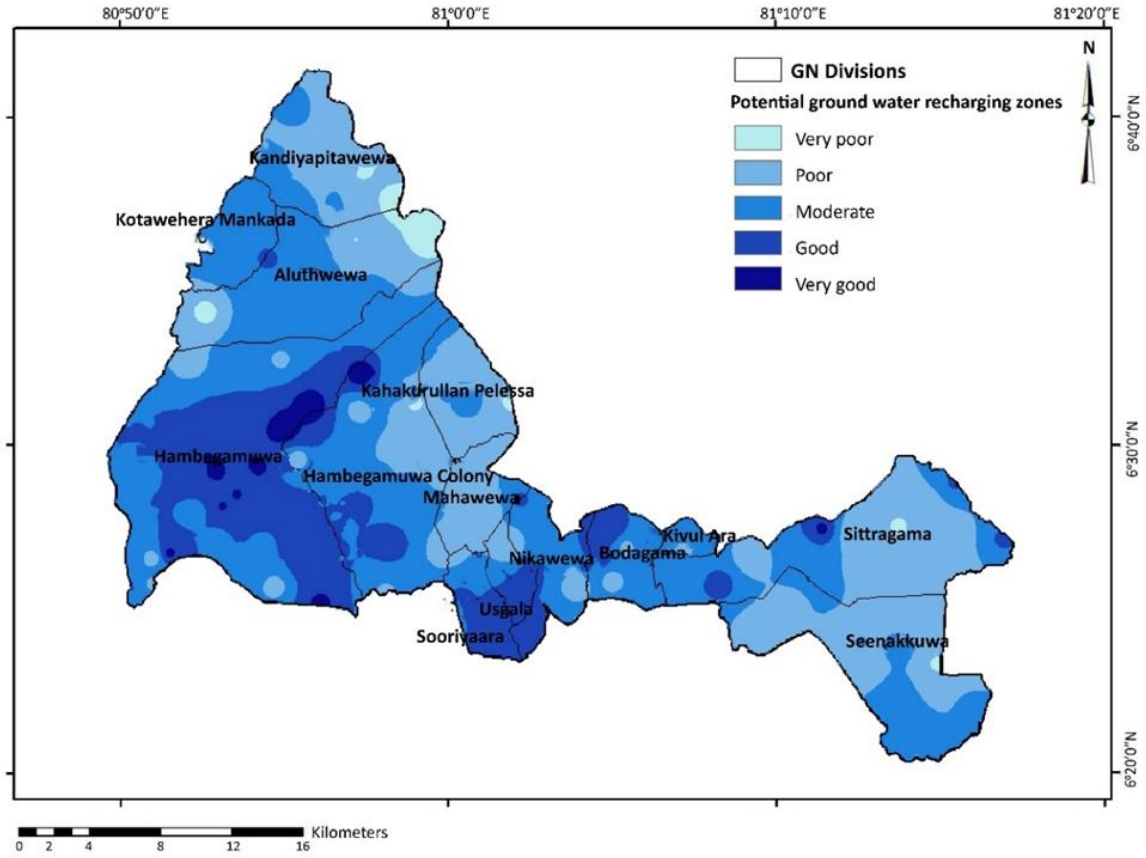

Figure 1. Groundwater recharging potential areas in Thanamalvila DSD

Conclusion

The present study identified that geological features such as low elevation, rainfall, and drainage networks significantly affect groundwater recharging in hard rock areas. It is recommended that this approach be applied to identify groundwater recharge zones in other dry areas of Sri Lanka as well.

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Selected References

Bhunia, G. S. (2020). *An approach to demarcate groundwater recharge potential zone using geospatial technology. Applied Water Science*, 10(6), 1–12. https://doi.org/10.1007/s13201-020-01214-z

DeNicola, E., Aburizaiza, O. S., Siddique, A., Khwaja, H., & Carpenter, D. O. (2015). *Climate change and water scarcity: The case of Saudi Arabia. Annals of Global Health*, 81(3), 342–353. https://doi.org/10.1016/j.aogh.2015.08.005

Jasechko, S., Perrone, D., Befus, K. M., Bayani Cardenas, M., Ferguson, G., Gleeson, T., Luijendijk, E., McDonnell, J. J., Taylor, R. G., Wada, Y., & Kirchner, J. W. (2014). *The pronounced seasonality of global groundwater recharge. Water Resources Research*, 50(11), 8845–8867. https://doi.org/10.1002/2014WR015809

Kariyawasam, T., Basnayake, V., Wanniarachchi, S., Sarukkalige, R., & Rathnayake, U. (2022). *Application of GIS techniques in identifying artificial groundwater recharging zones in arid regions: A case study in Tissamaharama, Sri Lanka. Hydrology*, 9(12), 224. https://doi.org/10.3390/hydrology9120224

Senanayake, I. P., Dissanayake, D., Mayadunna, B. B., & Weerasekera, W. L. (2016). *An approach to delineate groundwater recharge potential sites in Ambalantota, Sri Lanka using GIS techniques. Geoscience Frontiers*, 7(1), 115–124. https://doi.org/10.1016/j.gsf.2015.03.002

Udeshani, W. A. C., & Gunatilake, S. K. (2019). *Seasonal groundwater quality variation in Monaragala District of Sri Lanka* [Conference paper].

Thesis reference

Athauda, E.A.R.P.M.B. (2024), An Assessment of Groundwater Recharge Potential in the Thanamalvila Divisional Secretariat Division, Uva Province, Sri Lanka. MSc. Thesis, Post Graduate Institute of Science, University of Peradeniya.

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ASSESSMENT OF GROUNDWATER LEVEL AND DRINKING WATER QUALITY VARIATIONS IN A COASTAL AQUIFER: A CASE STUDY ON THE WEST COAST FROM COLOMBO TO NEGOMBO, SRI LANKA

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Coastal fresh groundwater is a vital resource playing a crucial role in supporting human life, ecosystems, and economic activities. As economics and populations continue to expand, the availability of freshwater on the surface is becoming limited due to increasing demand and pollution. This scarcity has led communities, particularly in coastal areas, to rely more on groundwater to meet their needs.

However, coastal groundwater contamination/pollution has presently emerged as one of the major global concerns. Coastal groundwater pollution occurs through the release of harmful substances to the underground aquifer by natural processes or anthropogenic activities. Irrigated agriculture, industrialization, urbanization, and seawater intrusion poses a threat to the deterioration of coastal groundwater quality and the depletion of water quantity.

Sri Lanka is an island in the Indian Ocean with a coastline of about 1600km in length. Here, the western coastal stretch from Colombo to Negombo is a key economic zone experiencing rapid development and high population density. As surface water becomes scarce or polluted, communities in this area rely heavily on groundwater, which is highly vulnerable to over-extraction, contamination from waste, fertilizer use, and seawater intrusion.

In order to ensure the long-term sustainability of these groundwater resources, integrated and sustainable water management practices are necessary. Regular monitoring of water levels and quality is crucial to safeguard drinking water supplies and protect coastal ecosystems.

Thus, the present study mainly focuses on groundwater level fluctuations over a period of 11 years from 2012 to 2023 and the assessment of groundwater quality in relation to the groundwater level fluctuation. This study aims to establish a correlation between variations in

water levels and changes in water quality. It also seeks to identify the extent of seawater intrusion in the Gampaha District, which includes several sub-administrative secretariats, namely Negombo, Ja-Ela, Katana, and Wattala.

Methodology

The study utilized secondary data such as topographic, geological, and structural maps, satellite imagery, and historical data to gain an initial understanding of the study area. Climatic information, including rainfall and temperature, was obtained from the Department of Meteorology, while population and drinking water source data were sourced from the Department of Census and Statistics to assess regional water use. Borehole logs and secondary data from the Water Resources Board were analyzed to delineate the project area, determine sampling distribution, and interpret subsurface conditions. A total of 32 tube wells were selected for this study. Chemical analysis and groundwater level records from 2012 to 2022 were used for assessment of water quality and level trends. Borehole stratigraphy was examined to identify aquifer positions and subsurface layering. A total of 32 tube wells were selected for this study, and groundwater samples were collected in pre-cleaned, airtight PTFE polyethylene bottles to prevent evaporation and contamination.

In-situ measurements of physical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), temperature, and salinity, were conducted using the HI 9829 multiparameter instrument, equipped with specific electrodes for pH (HI7609829-1) and EC (HI7609829-3). Conductivity depth profiling was performed in selected wells using a CTD diver (50 m) and an optical reading unit. All information was recorded on field data sheets. Heavy metal analysis was conducted annually. Most of the chemical analysis parameters, methods, and permissible levels are conducted according to the SLS portable water standard for drinking water 614:2013 requirements. Water level measurements and in-situ monitoring were also carried out twice per year.

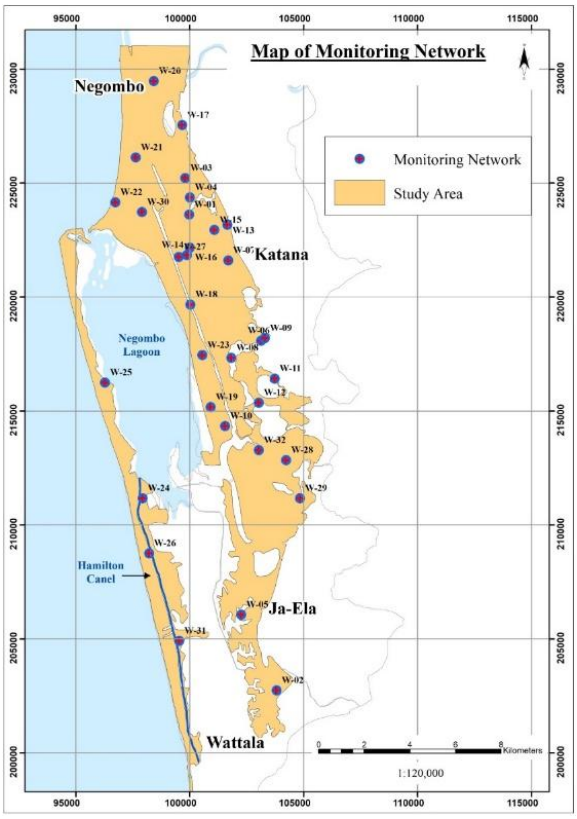

Figure 1. Map of monitoring network

Thematic maps were developed using ArcGIS 10.4 software. For spatial representation of chemical data, the Inverse Distance Weighted (IDW) interpolation method was applied. Outlier detection was performed using the Interquartile Range (IQR) method to ensure data quality, particularly for chemical data spanning 2012–2023. This involved calculating quartiles and identifying values outside the upper and lower limits as outliers. Graphical interpretation, thematic mapping, and outlier removal were applied specifically to parameters such as electrical conductivity, nitrate, and iron content.

Results and Discussion

According to the findings, groundwater level analysis indicated a nonlinear relationship between precipitation and aquifer recharge, with lateral inflows playing a significant role in moderating seasonal groundwater fluctuations and reducing the direct impact of rainfall on recharge. Rapid groundwater level decline was observed during dry periods, particularly in high-

demand areas such as the Katunayake Airport Zone, Export Processing Zone, and adjacent commercial zones, due to intensive groundwater abstraction. Long-term observations suggest that groundwater levels and quality in the region show weak correlation with precipitation patterns. Localized zones near Negombo Lagoon, Hamilton Lake, and coastal margins exhibit signs of seawater intrusion as well as elevated iron and nitrate concentrations. Electrical conductivity in the aquifer demonstrates an inverse correlation with precipitation, with lower values observed further inland. Nitrate and iron contamination appear to be spatially confined and are likely attributable to point sources. Most wells in the study area remain within acceptable nitrate limits, and nitrate pollution has not yet reached critical levels.

Conclusion

Overall, the findings suggest that a majority of the aquifer remains relatively less affected by significant groundwater depletion or widespread contamination by nitrate and iron.

Acknowledgment

This study was made possible through the support of Mr. R.R.G.R. Rajapakse, Assistant General Manager (Research and Development) of the Water Resources Board, Sri Lanka, for granting access to data from the LTGM Colombo–Negombo project and providing expert advice. Further professionals, including A. Egodawithana, Mrs. H.A.M. Prasadani, Mr. Madusanka Hemarathne, Mrs. Prasangi Bandara, and Mrs. G.V.N. Sajeewani, for their valuable insights and support throughout the research.

Selected References

Alley, W. M., Reilly, T. E., & Franke, O. L. (1999). *Sustainability of groundwater resources (U.S. Geological Survey Circular 1186).* U.S. Geological Survey.

Chandrajith, R., Dinusha, C., Abeykoon, S., Johannes, B., Geldern, V., Edirisinghe, R., & Viraj. (2014). *Quantification of groundwater–seawater interaction in a coastal sandy aquifer system: A study from Panama, Sri Lanka. Environmental Earth Sciences*, 72, Article 4023. https://doi.org/10.1007/s12665-014-4023-2

Dharmagunawardhane, H. A., & Edirisuriya, G. (2013). *Status of the productiveness of hard rock aquifers in Sri Lanka, as revealed from the yield of water supply boreholes: A case study from the hard rock terrain of Sri Lanka.* In *Groundwater resources assessment, recharge and modelling* (pp. 10–19).

Ratha, P., Nandalal, K. D. W., Pitawala, H. M. T. G. A., Dharmagunawardhane, H. A., & Weerakoon, S. B. (2018, July 13–14). *Groundwater vulnerability: A status review on North Western coastal aquifers of Sri Lanka, based on a GIS–DRASTIC assessment.* Paper presented at the *Sixth International Symposium on Water Quality and Human Health: Challenges Ahead*, PGIS, Peradeniya, Sri Lanka.

Vetrimurugan, E., Lakshman, E., & Natarajan, R. (2013). *Source of contaminants and groundwater quality in the coastal part of a river delta. International Journal of Environmental Science and Technology*, 10, 123–134. https://doi.org/10.1007/s13762-013-0251-4

Thesis reference

Dhananjaya, A.M. (2024), Assessment of groundwater level and drinking water quality variations in a coastal aquifer: a case study on the west coast from Colombo to Negombo, Sri Lanka. MSc. Thesis, Post Graduate Institute of Science, University of Peradeniya.

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ASSESSMENT OF GROUNDWATER POLLUTION VULNERABILITY IN THE JAFFNA PENINSULA USING A DRASTIC-LU INDEX METHOD: VALIDATION THROUGH SPATIAL NITRATE DISTRIBUTION ANALYSIS

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The Jaffna Peninsula in northern Sri Lanka relies exclusively on groundwater due to the absence of perennial rivers or major water supply schemes. However, over-extraction and water quality deterioration have become significant challenges, driven by excessive fertilizer use, intensive agriculture, population growth following post-war resettlement, and inadequate infrastructure maintenance. Notably, the shallow karstic aquifer system experiences a critical imbalance between water draw-off and recharge rates, exacerbating the region's vulnerability to salinity and contamination.

This study seeks to develop a comprehensive groundwater vulnerability map for the Jaffna Peninsula using a modified DRASTIC model. The model incorporates seven hydrogeological parameters: depth to aquifer, recharge, aquifer media, soil type, topography, vadose zone, and hydraulic conductivity, each assigned weights and ratings to assess pollution vulnerability. Modifications, including land-use parameters, were applied to refine the model and validate it against nitrate contamination data collected over a decade.

The primary objective is to develop a detailed groundwater contamination vulnerability map to support informed management decisions. Secondary objectives include: Identifying areas that require targeted interventions to prevent or mitigate groundwater contamination, classifying intrinsic aquifer properties to maintain

groundwater quality and identifying factors contributing to contamination, and validating the vulnerability map by examining its correlation with nitrate contamination data collected over ten years.

By integrating geospatial techniques, this study evaluates the impact of land use and physical environmental factors on groundwater vulnerability. The results provide valuable tools for policymakers to prioritize interventions, ensure sustainable resource use, and mitigate health and ecological risks associated with nitrate contamination.

Methodology

Groundwater is the sole water source in the Jaffna Peninsula, Sri Lanka, making its quality and sustainability critical. This study applies the modified DRASTIC index, incorporating additional parameters like land use, to evaluate groundwater vulnerability and establish correlations with nitrate contamination data.

The DRASTIC index incorporates seven hydrogeological parameters: Depth to groundwater (D), Recharge (R), Aquifer media (A), Soil media (S), Topography (T), Impact of vadose zone (I), and Aquifer hydraulic conductivity (C). The equation for DRASTIC is as follows:

$$DRASTIC\ Index = (D_R * D_W) + (R_R * R_W) + (A_R * A_W) + (S_R * S_W) + (T_R + T_W) + (I_R * I_W) + (C_R * C_W) \quad (1)$$

Ratings (R) and weights (W) for these parameters determine vulnerability. Shallow water tables, high recharge, and permeable aquifer media elevate pollution risks. Table 1 and Table 2 provide detailed parameter ranges and ratings.

The modified DRASTIC index incorporates land use as an additional parameter:

$$Modified\ DRASTIC\ Index = (D_R * D_W) + (R_R * R_W) + (A_R * A_W) + (S_R * S_W) + (T_R + T_W) + (I_R * I_W) + (C_R * C_W) + (LU_R * LU_W) \quad (2)$$

Here, LU represents land use, with weights and ratings shown in Table 3.

Table 1. DRASTIC Depth to Water (D), Recharge (R), Hydraulic Conductivity (C), and Topography (T)

Parameter	Weight	Range	Rating
Depth to Water (D)	5	0–3.5 m	10
		3.5–4.6 m	9
		4.6–9.1 m	7
		9.1–15.2 m	5
		15.2–22.8 m	3
		22.8–30.4 m	2
		>30.4 m	1
Net Recharge (R)	4	0–50.8 mm	1
		50.8–101.6 mm	3
		101.6–177.8 mm	7
		177.8–254 mm	8
		>254 mm	9
Hydraulic Conductivity (C)	3	0.04–4.1 m/day	1
		4.1–12.3 m/day	2
		12.3–28.7 m/day	4
		28.7–41 m/day	6
		41–82 m/day	8
		>82 m/day	10
Topography (T)	1	0–2% slope	10
		2–6% slope	9
		6–12% slope	5
		12–18% slope	3
		>18% slope	1

Table 2. DRASTIC Aquifer Media (A), Vadose Zone (I), and Soil Media (S)

Parameter	Weight	Material	Rating
Aquifer Media (A)	3	Massive shale	2
	3	Metamorphic/igneous rocks	3

Parameter	Weight	Material	Rating
		Weathered metamorphic/igneous rocks	4
		Thin-bedded sandstone, limestone, shale	6
		Sand and gravel	8
		Karst limestone	10
Vadose Zone (I)	5	Silt/clay	1
		Limestone	6
		Sand and gravel	8
		Karst limestone	10
Soil Media (S)	2	Non-shrinking clay	1
		Sandy loam	6
		Sand	9

Table 3. Land Use Ratings and Weights for Modified DRASTIC Method

Land Use Type	Rating	Weight
Irrigated field crop + urban areas	10	5
Irrigated field crop + grassland with poor vegetation cover + urban areas	9	5
Irrigated field crop + grassland with moderate vegetation cover + urban areas	8	5
Irrigated field crop	8	5
Irrigated field crop + fallow land + grassland with moderate vegetation cover + urban areas	7	5
Irrigated field crop + grassland with poor vegetation cover	7	5
Irrigated field crop + grassland with moderate vegetation cover	6	5
Irrigated field crop + rocky + urban areas	5	5
Irrigated field crop + grassland with poor vegetation cover + woodland	5	5
Irrigated field crop + woodland	5	5
Irrigated field crop + rocky	4	5
Fallow land	3	5
Fallow land + grassland with poor vegetation cover	3	5
Fallow land + grassland with moderate vegetation cover	3	5
Grassland with poor vegetation cover	2	5
Grassland with moderate vegetation cover	2	5
Grassland with moderate vegetation cover + woodland	1	5
Sand dune + grassland with moderate vegetation cover	1	5
Sand dune	1	5

Table 3 provides the complete classification of land use types, their ratings, and their assigned weights for the modified DRASTIC methodology. It highlights the influence of different land-use patterns on groundwater vulnerability, with urban and irrigated areas receiving the highest ratings due to their greater contamination risks.

According to the above rating and weighting criteria, 102 borehole locations were assessed, and eight raster maps were prepared and

interpolated using a GIS database to produce the final vulnerability map.

Using Pearson's correlation coefficient, a strong positive relationship was observed between vulnerability index values and nitrate concentrations. The equation for correlation is:

$$r = \frac{\Sigma[(Xi-\bar{x})(yi-\bar{y})]}{\sqrt{(\Sigma(xi-\bar{x})^2 \times \Sigma(yi-\bar{y})^2)}} \quad (3)$$

where xi and yi are the vulnerability index and nitrate concentration values, respectively, and $\bar{x}$ and $\bar{y}$ are their respective means.

Results indicated nitrate hotspots aligned with high vulnerability zones, underscoring the impact of land use and recharge rates.

The study indicated the aquifer in the region exhibits a moderate to high level of vulnerability, covering a total area of 1,025 km^2.

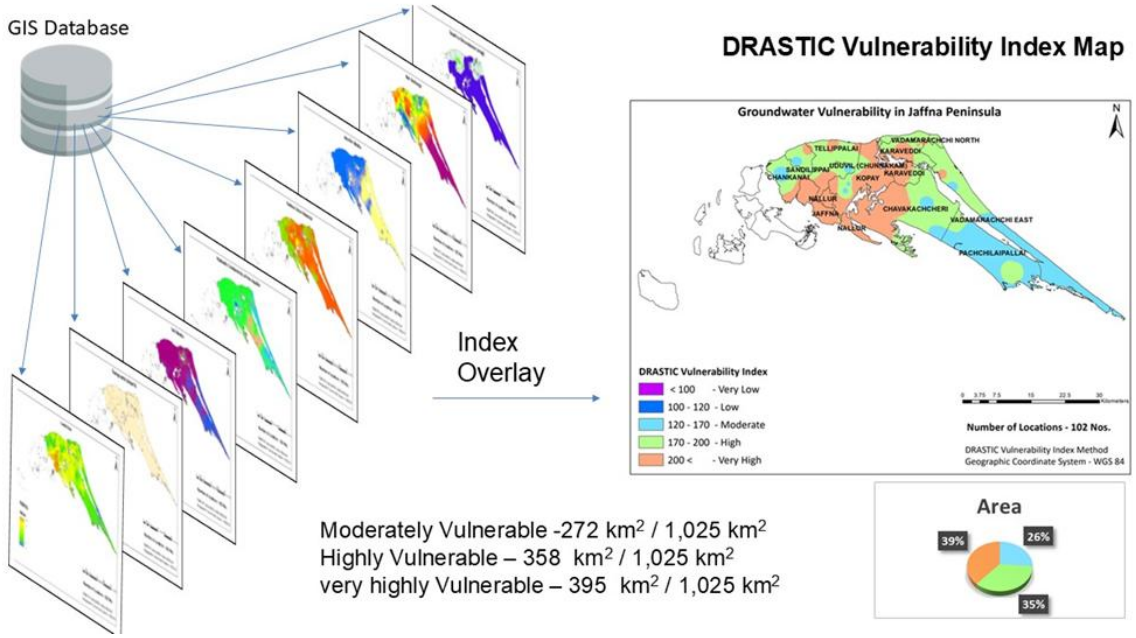

Figure 1. Generation of the DRASTIC vulnerability index map by overlaying eight thematic layers: The vulnerability index map was prepared by index overlay method within a Geodatabase in Arc GIS

Results and Discussion

Within this expanse, 272 km^2 (26%) areas are classified as moderately vulnerable, 358 km^2 (35%) as highly vulnerable, and 395 km^2 (39%) as very highly vulnerable.

Groundwater in the Jaffna Peninsula is generally shallow and seasonally fluctuates, with recharge increasing during the northeast monsoon. The region's karstic limestone aquifers, especially in areas like Jaffna, Kopai, and Nallur, are highly permeable, enabling rapid recharge but also increasing vulnerability to contamination. Soil texture, particularly sandy and sandy loam types in regions like Wadamarachchi and Pachchilapallai, further facilitates percolation and pollutant transport. Flat terrain, thin vadose zones, and high hydraulic conductivity-especially in porous karst areas-intensify contamination risks. Land use patterns, including agriculture and urbanization, influence groundwater quality, with nitrate contamination notably linked to both hydrogeological conditions and human activities.

A positive correlation between nitrate levels and vulnerability indices highlights the impact of land use and aquifer characteristics on groundwater quality.

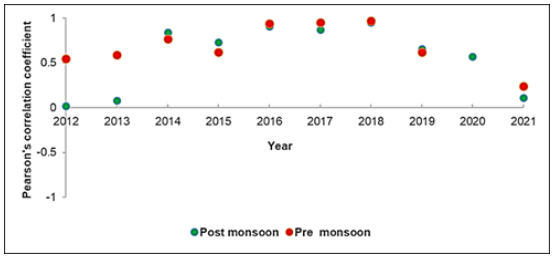

Figure 2. Graph of Calculated Pearson's Correlation Coefficients

Conclusion

Groundwater in the Jaffna Peninsula is highly susceptible to contamination, with 74% of the area classified as highly to very highly vulnerable. The combination of shallow, seasonally fluctuating aquifers, permeable karstic limestone, sandy soils, and thin vadose zones accelerate pollutant transport and increase risk. Land use practices, particularly agriculture and urbanization, further exacerbate contamination, as reflected by the strong correlation between nitrate levels and vulnerability indices. These findings emphasize the critical need for sustainable groundwater management and land use planning in the region.

Selected References

Aller, L., Bennett, T., Lehr, J. H., Petty, R. J., & Hackett, G. (1987). *DRASTIC: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings (EPA/600/2-87/035).* U.S. Environmental Protection Agency.

Barbulescu, A. (2020). *Assessing groundwater vulnerability: DRASTIC and DRASTIC-like methods: A review. Water*, 12(5), 1356. https://doi.org/10.3390/w12051356

Gunaalan, K., Asanthi, H. B., Gamage, T. P. D., Thushyanthy, M., & Saravanan, S. (2018). *Geochemical variations of groundwater quality in coastal and karstic aquifers in Jaffna Peninsula, Sri Lanka.* In *Management of Water, Energy and Bio-resources in the Era of Climate Change: Emerging Issues and Challenges* (pp. 51–61).

Johnson, A. B. (2019). *Groundwater flow in limestone aquifers: A case study of the Jaffna Peninsula. Hydrogeology Journal*, 27(3), 125–142. https://doi.org/10.1007/s10040-018-1891-5

Kazakis, N., Voudouris, K., & Karatzas, G. P. (2014). *Groundwater vulnerability and risk mapping using GIS, modeling, and a fuzzy logic tool. Journal of Hydroinformatics*, 16(5), 1069–1087. https://doi.org/10.2166/hydro.2014.062

Spalding, R. F., & Exner, M. E. (1993). *Occurrence of nitrate in groundwater—A review. Journal of Environmental Quality*, 22(3), 392–402. https://doi.org/10.2134/jeq1993.00472425002200030009x

Vrba, J., & Zaporozec, A. (1994). *Guidebook on mapping groundwater vulnerability (International Contributions to Hydrogeology, Vol. 16).* International Association of Hydrogeologists.

Publications

Abeysinghe, A. M. N. P. B., Rajapakse, R. R. G. R., & Prasadani, H. A. M. (2022). *Hydrogeological characterization and spatiotemporal variation of groundwater chemistry at Lakvijaya coal-fired thermal power plant area, Norochcholei, Sri Lanka.* In *International Water Conference, Hydrology & Hydrogeology* (Vol. 7, pp. 198–205).

Abeysinghe, M. N. P. B., Prasadani, H. A. M., & Rajapakse, R. R. G. R. (2018). *Assessment of hydrogeological conditions using resistivity data: A case study in Moragahakanda area, Sri Lanka.* In *PGIS Research Congress of University of Peradeniya, Science* (Vol. 14).

Ariyakumara, W. A. S. K., Prasadani, H. A. M., & Ekanayake, E. M. N. H. (2019). *A study for calculation of effective rainfall threshold values for initiation of landslides in several divisional secretariats in Kalutara District, Sri Lanka.* In *Technical Session of Geological Society of Sri Lanka, Earth Science* (Vol. 35, p. 30).

Egodawithana, A., Rajapakse, R. R. G. R., & Prasadani, H. A. M. (2023). *Assessment of long-term groundwater level and quality variations in western coastal sandy aquifers of Sri Lanka.* In *International Water Conference, Hydrology & Hydrogeology* (Vol. 4, pp. 158–165).

Ekanayake, E. M. N. H., Prasadani, H. A. M., & Ariyakumara, W. A. S. K. (2019). *Analysis of road cutting failure and designing of countermeasures—A case study along the Bulathsinhala–Horana Road, Kalutara District, Sri Lanka.* In *Annual Symposium of National Building Research Organization, Disaster Management* (Vol. 9, pp. 289–298).

Prasadani, H. A. M., Abeysinghe, A. M. N. P. B., Chandrajith, R., Weerasooriya, R., & Marambe, B. (2019). *Adsorption of arsenate and arsenite onto reddish brown earth (RBE) in the presence of glyphosate. International Journal of Scientific & Engineering Research, Science & Engineering*, 10(2), 491–496.

Thesis reference

Prasadani, H.A.M. (2024). Assessment of Groundwater Pollution Vulnerability in the Jaffna Peninsula Using a DRASTIC -LU Index Method: Validation Through Spatial Nitrate Distribution Analysis.

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ASSESSMENT OF SURFACE WATER CHEMISTRY IN THE THELGAMUWA OYA SUB CATCHMENT, SRI LANKA

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Surface water is a vital component of Earth's hydrosphere, serving as a cornerstone for various ecological, social, and economic activities. It encompasses rivers, lakes, wetlands, and reservoirs, providing essential freshwater resources for human consumption, agriculture, industries and ecosystem services. These water bodies are not only crucial for meeting daily water needs but also play a pivotal role in supporting biodiversity by creating habitats for aquatic species and maintaining ecological balance. Moreover, surface water contributes significantly to climate regulation and weather patterns through its involvement in the hydrological cycle, influencing precipitation, evaporation, and groundwater recharge processes. Thus, the conservation and sustainable management of surface water are essential for ensuring water security, environmental sustainability, and the resilience of ecosystems and communities.

Surface water contamination is a critical environmental concern resulting from the introduction of pollutants into rivers, lakes, reservoirs, and wetlands. Major sources include industrial effluents, untreated sewage, agricultural runoff, and urban storm water, which release nutrients, heavy metals, pathogens, and toxic chemicals into aquatic systems. These contaminants degrade water quality, disrupt ecosystems, and contribute to issues such as eutrophication, biodiversity loss, and the spread of waterborne diseases. Heavy metal accumulation and microplastic pollution further threaten food safety and human health. Effective management requires stringent wastewater treatment, pollution control policies, sustainable agricultural practices, and regular water quality monitoring.

The Mahaweli river receives several tributaries originating from the Knuckles Conservation Forest, including the Thelgamuwa Oya, Barawardhana Oya, Moragahaulpatha–Namini Oya, Kalu Ganga, Heen Ganga, Hasalaka Oya,

and Sudu Ganga. This study concentrates on the hydrogeochemical characteristics of the Thelgamuwa Oya sub-catchment. Knuckles Conservation Forest belongs to the intermediate zone of Sri Lanka whch is situated at coordinates 7°26′32.01″ N and 80°46′52.03″ E, with a total land area of approximately 21,000 hectares. The average annual rainfall in the region is approximately 4000 mm, with nearly 75% of which is received during the North-East monsoon period (Maha season) which occur from October to January. The remaining period of the year is dry with the peak of the dry season (Yala season) being May to September (Bandara, 2003). The average monthly temperature ranges from 18-32 °C.

The Thelgamuva Oya sub-catchment is located on the northwest side of the Knuckles Conservation Forest, covering 40.5 km². As of now, the Irrigation Department has not measured any flow rate for the Thelgamuva Oya, and it flows directly into the Moragahakanda reservoir.

The density of paddy land is relatively high in this area, increasing the likelihood of agrochemicals entering the main water body from these regions. Additionally, the elevation differentials are relatively high, creating steeper terrain and thereby increasing the chances of greater movement of agrochemicals from upstream to downstream points.

Methodology

The study aims to identify the most affected and vulnerable areas of surface water, evaluate their current chemical status, and analyze the spatio-temporal variations in hydrogeochemistry across the study area. Seventeen water sampling points were selected to assess the surface water chemistry in the Thelgamuwa Oya sub-catchment, Seventeen water samples were taken to determine pH, Electrical conductivity (EC) and Total Dissolved Solids (TDS), 6 water samples were taken to determine Bilogical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), and 4 water samples were taken to determine the content of Cadmium (Cd), Arsenic (As) and Mercury (Hg) from the selected seventeen water sampling points.

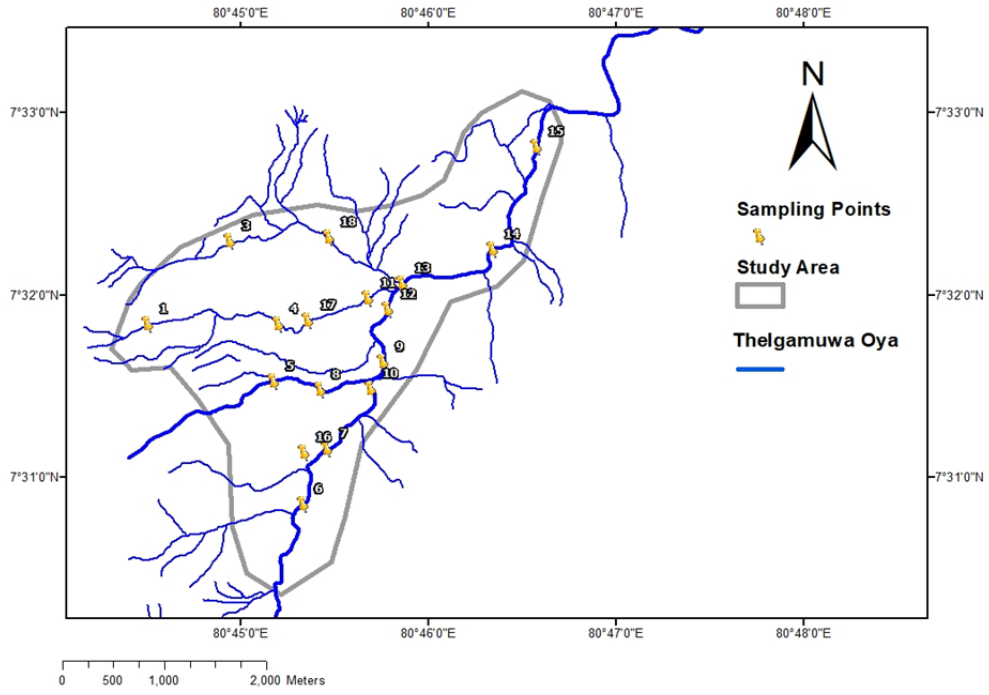

Figure 1. Sampling points distribution through the study area

Results and Discussion

According to the results in Table 1, only pH exceeded the permissible level, while heavy metals were not detected in any of the analyzed samples. The overall results show that most of the parameters tested in the quality survey were below the permissible limits of Sri Lankan standards for potable water.

Table 1. Summary of water quality analysis

Parameter	Max	Min	Mean	MDL	MPL
1. TDS in mg/L	59	8	20.9	500	2000
2. pH at 250 °C ± 20 °C	8.7	7.2	8.2	7.0 - 8.5	6.5 - 9.0
3. Electrical Conductivity in µS/cm	118	16	43.9	750	3500
4. COD in mg/L	15	2	6.2	10	20
5. BOD in mg/L	2.5	0.1	0.9	3	6
6. Cd in ppm	ND	ND	ND		
7. As in ppm	ND	ND	ND		
8. Hg in ppm	ND	ND	ND		

Results indicate that there is no significant difference in the water quality in the Thelgamuwa Oya sub-catchments. According to the results, only pH exhibit values higher than the desirable levels. Comparing the other sub-catchments, the highest mean pH value was found in the surface water of the Thelgamuwa Oya sub-catchment. TDS and EC values are within the maximum desirable level. Furthermore, BOD and COD levels are lower than the standard level, indicating minimal impact of these factors in the selected area. No heavy metals were detected in any of the analyzed samples at ppm levels. However, due to the high elevation profile, agrochemicals may be transported downstream and accumulated in reservoirs and tanks.

Conclusion

A proper management plan is essential to preserve the groundwater resources of the sub-catchment area. This plan should include the implementation of awareness programs as well as rules and regulations aimed at preventing water pollution. Future studies should focus on detecting heavy metals at parts per billion levels in the sub-catchment. It is recommended to reevaluate the groundwater and surface water chemistry quarterly and to take water samples distributed evenly across the sub-catchments. This will provide a detailed understanding of the sub-catchments before any infrastructure development or other major projects are undertaken.

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Green Movement of Sri Lanka (GMSL)

Selected References

Bandara, K. M. P. S. (2003). *Monitoring irrigation performance in Sri Lanka with high-frequency satellite measurements during the dry season. Agricultural Water Management*, 58(2), 159–170. https://doi.org/10.1016/S0378-3774(02)00080-3

Barbier, E. B., Acreman, M., & Knowler, D. (2016). *The importance of wetlands in the context of climate change and water resource management. Ecological Economics*, 136, 152–161.
https://doi.org/10.1016/j.ecolecon.2016.03.020

Intergovernmental Panel on Climate Change (IPCC). (2019). *Special report on climate change and land.* Intergovernmental Panel on Climate Change.

UN Water. (2021). *Water for a sustainable world.* United Nations.

Villholth, K. G., & Rajasooriyar, L. D. (2010). *Groundwater resources and management challenges in Sri Lanka: An overview. Water Resources Management*, 24(7), 1489–1513. https://doi.org/10.1007/s11269-009-9506-4

Thesis reference

Jeewantha H.J.M. A., (2024). Assessment of surface water chemistry in the thelgamuwa oya sub catchment, sri lanka, M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya.

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AWARENESS AND PREPAREDNESS FOR FIRE EMERGENCIES IN THE EYE UNIT OF NATIONAL HOSPITAL, KANDY, SRI LANKA

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Sri Lanka, classified as a developing country, faces unique social and economic challenges. The country is vulnerable to various environmental and societal threats, including floods, droughts, landslides, epidemics, wars, environmental degradation, ozone depletion, and oceanic erosion. In addressing these challenges, the Disaster Management Centre (DMC) serves as a key authority, particularly for natural disasters, while the Ministry of Health and the healthcare system play a pivotal role in managing epidemic-related disasters. Given the country's susceptibility to both natural and man-made disasters, the healthcare system serves as a central hub in disaster response.

Hospitals, particularly tertiary care facilities, are critical during disaster situations. Teaching hospitals, considered pioneers in disaster management, are generally well-prepared for mass casualty operations. The main teaching hospital in the central province actively works on emergency preparedness plans, but only a limited number of healthcare workers are deeply engaged in this area, while other staff members often lack comprehensive knowledge until urgent situations arise. Internal emergencies, especially fire hazards, frequently take precedence, reflecting a global pattern. Patients admitted for treatments are particularly vulnerable, emphasizing the responsibility of healthcare workers to maintain a safe and patient-friendly environment.

Recognizing hazardous events and locations can enhance patient safety and minimize the impact of internal emergencies. However, the absence of a designated authority to oversee action plans and decisions regarding internal emergencies raises concerns about the clarity and accountability of preparedness efforts.

Methodology

This research aims to assess and enhance the preparedness of the healthcare system, particularly hospitals, for a spectrum of disasters,

both natural and internal, in Sri Lanka. Specifically, the study focuses on the ophthalmology unit of National Hospital, Kandy (NHK) and seeks to:

a. Examine the primary internal factors contributing to fire hazards within the eye unit.
b. Assess the level of preparedness and vulnerabilities in the unit concerning fire hazards and disaster response.
c. Evaluate the educational background, training, and awareness of healthcare team members regarding fire hazard preparedness.
d. Develop and implement floor-specific fire escape plans based on the layout of the eye unit.
e. Establish an internal disaster management protocol to address fire hazards.

This mixed-methods study combines descriptive statistical analysis with qualitative assessment at the eye unit of NHK, Sri Lanka. Ethical clearance was obtained from the National Hospital, Kandy, Sri Lanka. Primary data was collected using questionnaires administered to hospital staff. A total of 100 questionnaires were distributed, and only 44 complete responses were received. Additionally, on-site observations were conducted to assess the accessibility of safe areas, availability of fire escapes, and adequacy and functionality of fire extinguishing equipment, verified with fire crews. Semi-structured interviews were also conducted with members from the maintenance, hospital authority, and planning units of NHK. Data were preprocessed using MS Excel and analyzed using Minitab v18.0.

Results and Discussion

The analysis of demographic characteristics and disaster awareness among hospital staff provided valuable insights into preparedness and response capabilities within the ophthalmology unit at NHK. As shown in Figure 1, most participants were female, reflecting the overall workforce composition the unit. Age, educational qualification, occupation, and working period were examined to assess their influence on staff awareness regarding technological hazards and internal emergency protocols. The ability to recognize technological hazards varied considerably across occupational categories: doctors demonstrated the lowest proportion (<10%) of staff unable to identify hazards, whereas attendants and minor staff had the highest proportion (45.45%). This suggests that professional training and exposure to clinical environments may enhance hazard recognition, while non-clinical staff may require additional targeted training.

Chi-square association tests (Table 1) revealed that among the demographic variables, educational qualification was the only factor significantly associated with awareness levels ($p< 0.05$). In contrast, gender, occupation, and years of experience did not show significant relationships with awareness. These findings highlight that formal education plays a pivotal role in equipping staff with the knowledge required for disaster preparedness, while experiential factors alone may not suffice. Despite the observed willingness of most staff members to participate in disaster response, there was a notable gap in practical knowledge related to critical internal safety measures, including operating fire extinguishers, locating fire exits, understanding bed capacity, and awareness of essential resources such as water, fuel, and medical supplies.

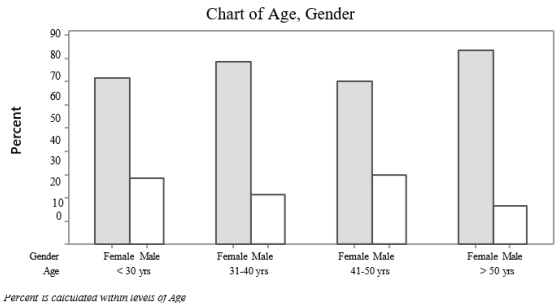

Figure 1. Composition of age versus gender

Table 1. Chi-square association between demographic variables and the awareness

	Gender	**Educational Qualification**	**Working Period**	**Occupation**
Fire Extinguisher. Operation	0.848	0.067	0.366	0.495
Fire Emergency Line	0.159	0.162	0.953	0.347
About the Responses	0.170	0.082	0.723	0.580
Disaster Response Plan	0.475	0.605	0.292	0.444
Fire Exits	1.000	0.129	0.925	0.624
Incident Command Center	0.340	0.067	0.792	0.080
Fire Detective System	1.000	0.697	0.177	0.465
Bed Capacity	0.812	0.535	0.375	0.672
Warning System	0.340	0.009*	0.843	0.495

Observational assessments of the ophthalmology unit revealed additional challenges related to structural preparedness. Fire escape plans for all floors, from basement to third floor were evaluated, showing that while escape routes were mapped, accessibility and adequacy of safety equipment varied across locations. In some cases, fire extinguishers were inadequately maintained or difficult to access, and signage was insufficient to guide staff and patients during emergencies. These findings underscore the need for continuous monitoring and regular updates of internal disaster protocols.

The analysis also highlighted the limited participation of hospital staff in disaster drills, despite their expressed willingness to serve during emergencies. This discrepancy suggests that intention alone is insufficient for effective preparedness and that structured training programs and mandatory drills are essential to bridge the gap between knowledge and action. Furthermore, knowledge retention appeared to be influenced by occupation and educational background; staff with higher qualifications demonstrated better awareness of disaster protocols, whereas minor staff and attendants showed significant deficiencies in understanding critical emergency procedures

Taken together, these findings indicate that internal disaster preparedness within the hospital is currently uneven, with significant gaps in staff awareness, training, and structural readiness. Addressing these deficiencies requires a multi-faceted approach that includes targeted training for all occupational groups, improved accessibility and maintenance of emergency equipment, clear signage, and the establishment of a designated authority to oversee internal disaster management. By implementing these measures, hospitals can enhance the safety of patients and staff and improve their capacity to respond effectively to fire hazards and other internal emergencies.

Conclusion

Overall, the study demonstrates the urgent need to enhance disaster preparedness within hospitals,

particularly regarding fire hazards. Random gaps in staff knowledge and limited engagement in emergency drills indicate that awareness and practical readiness require improvement. Establishing floor- specific fire escape plans, informed by staff educational backgrounds, and implementing robust communication systems are essential steps to strengthen internal emergency protocols. By addressing these gaps and promoting active participation among healthcare workers, hospitals can improve resilience, ensure patient safety, and effectively respond to a range of internal emergencies, ultimately mitigating the impact of disasters on both personnel and the wider community.

Selected References

Brigl, B., Ammenwerth, E., Dujat, C., Gräber, S., & Winter, A. (2005). Preparing strategic information management plans for hospitals: A practical guideline. *International Journal of Medical Informatics, 74*(1), 51–65. https://doi.org/10.1016/j.ijmedinf.2004.08.003

George, P., Yi, S. K., Paul, J. A., & Lin, L. (2010). Hospital capacity planning for disaster emergency management. *Socio-Economic Planning Sciences, 44*(3), 151–160. https://doi.org/10.1016/j.seps.2009.11.002

Gowing, J. R., Walker, K. N., Elmer, S. L., & Cummings, E. A. (2017). Disaster preparedness among health professionals and support staff: What is effective? An integrative literature review. *Prehospital and Disaster Medicine, 32*(3), 321–328. https://doi.org/10.1017/S1049023X1700019X

Kulkarni, R., Giri, P., & Gangwal, P. (2016). Knowledge and practices regarding fire safety amongst health care workers in tertiary care teaching hospital in Marathwada region of Maharashtra, India. *International Journal of Community Medicine and Public Health, 3*(7), 1900–1904. https://doi.org/10.18203/2394-6040.ijcmph20162047

Labrague, L. J., Hammad, K., Gloe, D. S., McEnroe-Petitte, D. M., Fronda, D. C., Obeidat, A. A., Leocadio, M. C., Cayaban, A. R., & Mirafuentes, E. C. (2018). Disaster preparedness among nurses: A systematic review of literature. *International Nursing Review, 65*(1), 41–53. https://doi.org/10.1111/inr.12369

Robinson, K. M., Lee, C., Wendt, K., & Williamson, D. (2009). The preparedness of hospital health information services for system failures due to internal disasters. *Health Information Management Journal, 38*(3), 27–33. https://doi.org/10.1177/183335830903800305

Thesis reference

Rathnayake, R.M.K.E. (2024). Awareness and preparedness for fire emergencies in the Eye Unit of National Hospital, Kandy. MSc Thesis, Postgraduate Institute of Science (PGIS), University of Peradeniya, Sri Lanka.

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DISASTER RISKS IN WASTE DISPOSAL SITES IN WESTERN PROVINCE, SRI LANKA

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A disaster is an occurrence that disrupts the normal conditions of existence and causes a level of suffering that exceeds the capacity for adjustment of the affected community. Pollution and threats caused by waste can be considered as disasters and cause harm to the public and society. Sri Lanka faces escalating municipal solid waste challenges due to rapid urbanization and population growth, with the Western Province generating the highest volumes and grappling with environmental, health, and socio-economic impacts from inadequate waste disposal practices. While integrated solid waste management initiatives including recycling, composting, and waste-to-energy projects are advancing, persistent issues like insufficient infrastructure, public awareness, and regulatory enforcement hinder sustainable waste solutions nationwide.

The research problem is inefficient solid waste management practices, particularly open dumping in Sri Lanka, pose significant disaster risks including landslides, flooding, and environmental and health hazards that urgently require systematic investigation and mitigation to protect urban communities.

This research aims to study disaster risks in Waste Disposal Sites in Western Province and provide guidelines to mitigate future risks in them. This study strived to achieve several objectives. Firstly, to develop a method for identifying suitable locations for waste disposal sites. Secondly, to investigate disaster risks associated with Waste Disposal Sites. Thirdly, to propose solutions/guidelines to mitigate or prevent future disaster risks of waste disposal site.

Disaster risk involves factors affecting the likelihood and impact of disasters across social, economic, and environmental dimensions, while waste defined as unwanted material with growing generation driven by development, urbanization, and population growth is categorized into types such as municipal, hazardous, medical, and radioactive, with global municipal solid waste

projected to increase by 70% from 2016 to 2050, posing significant management challenges.

Selecting suitable waste disposal sites requires considering multiple criteria such as proximity to roads, water bodies, residential and agricultural areas, geological and topographical factors, environmental sensitivities, and infrastructure to minimize environmental pollution, health risks, and operational costs, as supported by extensive literature.

Disaster risks at waste disposal sites arise from factors such as drain blockage, slope instability, soil and hydrological conditions, biogas explosions, excessive garbage volume, water table fluctuations, and extreme weather events, as exemplified by the catastrophic 2017 Meethotamulla landfill failure. Waste disposal sites pose significant disaster risks including flooding from blocked drainage, garbage landslides caused by slope instability, heavy rainfall as exemplified by the 2017 Meethotamulla landfill collapse, highlighting the critical need for effective solid waste management to mitigate public health, environmental, and economic impacts.

Inadequate solid waste management in developing urban areas leads to extensive environmental degradation, public health hazards including respiratory, infectious, and chronic diseases, soil, water, and air pollution, biodiversity loss, decreased property values, and socio-economic challenges such as visual and noise pollution and fire risks, underscoring the critical need for improved waste disposal practices.

Effective waste management depends on the coordinated involvement of diverse stakeholders including government ministries, local authorities, regulatory bodies like the Central Environmental Authority, private sector, NGOs, INGOs, informal recyclers, and community groups whose collaboration and conflict resolution are crucial for achieving sustainable waste solutions.

Solid waste management encompasses diverse strategies including integrated systems of reduction, recycling, composting, and safe disposal to protect health, environment, and economic development, with global and national practices ranging from community-based flood mitigation and zero-waste policies to specific responses like Sri Lanka's post-Meethotamulla initiatives involving waste separation, energy generation, and green job creation. Municipal Solid Waste management must be financially, technically, socially, and environmentally viable, with various treatments such as recycling, composting, upcycling, landfilling, and waste-to-energy technologies offering viable solutions. Among these, sustainable options like sanitary landfilling, composting, and recycling are favored over open dumping and unsanitary practices, which pose significant environmental and health risks.

Methodology

The Western Province, Sri Lanka's most urbanized region and source of over half the nation's waste, was selected as the study area due to its rapidly increasing municipal solid waste generation projected to rise from 3,850 to 4,157 metric tons daily between 2018 and 2023 and its 21 existing waste disposal sites across Colombo, Gampaha, and Kalutara districts.

To study and mitigate disaster risks in waste disposal sites in Sri Lanka, samples were gathered from literature and both formal and informal stakeholder groups involved in waste management. The sample sizes were determined using judgmental sampling, a non-probability technique that targeted relevant stakeholder groups. Before conducting the suitability analysis of waste disposal sites, a purposive sample of 20 professionals with relevant knowledge and experience was selected. Following the identification of the most vulnerable sites with very low and low suitability, a second sample of 18 representatives from formal stakeholder groups was engaged to assess disaster risks and propose mitigation measures. Finally, to capture community perspectives on disaster risks and impacts, a third sample comprising 28 individuals from nearby communities and beneficiary groups was gathered from seven highly unsuitable waste disposal sites. Data collection encompassed both

primary and secondary sources. A mixed-method approach was employed, combining qualitative insights into stakeholder perceptions of waste disposal sites and management with quantitative analysis to determine relevant percentages for waste disposal practices. Data were collected through questionnaire surveys targeting professional experts, formal and informal stakeholder groups, and through field observations conducted at the most unsuitable waste disposal sites.

Under data analysis, suitability analysis was conducted using ArcGIS based on criteria such as proximity to road network, railway line, water bodies (streams and tanks), population, housing, slope (5 m contour line), land use composition and town/villages, with waste disposal sites classified into six categories ranging from 0 (Not Suitable) to 5 (Very Highly Suitable) (Table 1).

Table 1. Table showing Classification of Suitability

No	Suitability	Score Value	Level of suitability	Color Range
1	0	0	Not Suitable	
2	1	1	Very Low Suitable	
3	2	2	Low Suitable	
4	3	3	Moderate Suitable	
5	4	4	High Suitable	
6	5	5	Very High Suitable	

After reclassifying all criteria, the relative influence of each criterion was determined based on responses from the questionnaire survey and weighted overlay analysis was conducted to integrate them into a single composite layer.

Following the weighted overlay analysis, the final output was classified into five suitability levels: Very High, High, Moderate, Low, and Very Low. Existing waste disposal sites were overlaid on this output, enabling the identification of unsuitable sites located within areas of low and very low suitability.

Disaster risk factors associated with waste disposal sites were identified through a comprehensive approach involving a literature review, questionnaire surveys, and field observations. The study covered 46 selected sample size, with data collected from both formal and informal stakeholder groups. A total of 16 samples were obtained per site to ensure data reliability and representativeness. The findings, quantified as percentages, revealed several critical factors contributing to disaster risk (Fig.1.). These are high height, garbage volume, water table fluctuation, the hydrology system, consecutive explosions due to biogas and leachate circulation.

Disaster risks in waste disposal sites were identified through literature review, questionnaire surveys, and field observations, incorporating input from formal and informal stakeholder groups with a sample of 16 per site across 46 selected unsuitable waste disposal sites, and analyzed using percentage (Fig.1.). Applied disaster risks of waste disposal sites were flood, garbage landslide, health impacts, land pollution, soil pollution, water pollution, air pollution, loss of biodiversity, visual pollution, noise pollution and fire hazard.

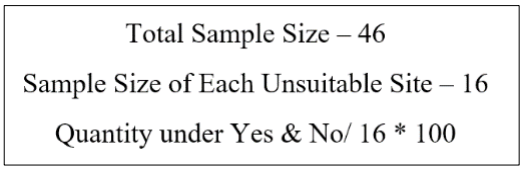

Figure 1. Calculation of identify disaster risk factors associated with waste disposal sites and disaster risks in waste disposal sites

The analysis of buildings located within a 500 m buffer of waste disposal sites was carried out using the ArcGIS mapping tool. Disaster prediction analysis was performed by evaluating factors and Disaster Risks exceeding a 50% agreement threshold from questionnaire surveys,

alongside assessing impacts on nearby communities for each selected waste disposal site. Solutions and guidelines for mitigating disaster risks at unsuitable waste disposal sites were identified through literature review, secondary data, and questionnaire surveys involving both formal and informal stakeholder groups, leading to the development of various alternative strategies.

Results and Discussion

A total of 21 waste disposal sites in the Western Province were evaluated for suitability using eight criteria, including proximity to road network, railway lines, streams and tanks, population, housing, slope, land use composition and towns/villages.

Weighted overlay analysis identified varying levels of suitability, with sites such as Kochchikade Owitiyawatta, Manelgamuwa, Bloemendal, Meethotamulla, Kotikawatta, Karadiyana, and Wethumarajapura classified as "very low" or "low," indicating limited suitability for waste disposal activities (Fig.2.).

An assessment of disaster risk factors across seven sites revealed considerable variability in potential hazards. The Karadiyana site recorded the highest risk (99%), while Meethotamulla showed the lowest risk (29%). These disparities highlight significant differences in vulnerability across locations and underscore the need for site-specific risk management strategies, particularly for highly exposed sites.

An analysis of disaster risk levels at seven waste disposal sites reveals considerable disparities in potential hazard exposure. The Karadiyana site exhibits the highest disaster risk (100%), while Meethotamulla shows the lowest risk (55%). These findings underscore the need for prioritized mitigation measures, particularly at the most vulnerable sites.

Spatial analysis of surrounding structures further emphasized potential community exposure. Meethotamulla and Kotikawatta had the highest proportion of nearby buildings, indicating significant potential impact on surrounding populations in case of hazardous events. In contrast, Bloemendal , Kochchikade Owitiyawatta , Karadiyana , Wethumarajapura , and Manelgamuwa presented relatively lower immediate risks to adjacent settlements. These findings suggest that urban planning and community safety considerations should be integrated into waste management strategies to mitigate local hazards effectively.

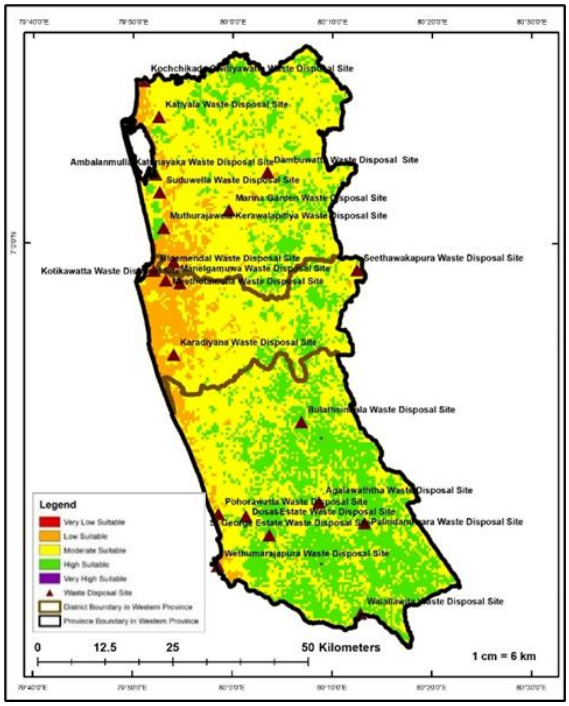

Figure 2. Map showing final output of suitability level of waste disposal sites

Stakeholder surveys proposed a range of interventions for unsuitable sites, including waste separation systems, composting, waste-to-energy conversion, recycling, bio-mining, and site-specific rehabilitation strategies. Collectively, these measures aim to address various waste types and environmental risks, promoting sustainable waste management through technological, regulatory, and land-use interventions.

Conclusion

The analysis revealed that the identified unsuitable waste disposal sites are highly vulnerable to disaster risks, with notable variation

among locations. The Karadiyana site exhibited the highest disaster risk at 100%, while Manelgamuwa and Kotikawatta each recorded significant risks of 90%. Kochchikade Owitiyawatta and Wethumarajapura both showed disaster risks of 80%, followed by Bloemendal at 76%. Meethotamulla displayed the lowest, though still considerable, disaster risk at 55%. Additionally, all these sites were situated within 500 m buffer zones encompassing over 100 residential buildings, indicating substantial potential impacts on nearby communities. These findings underscore the urgent need for risk mitigation and improved waste management practices in these areas and provide valuable insights for urban planning and the prioritization of interventions to enhance community safety.

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Selected References

Abeysinghe, M. N. P. B., Prasadani, H. A. M., & Rajapakse, R. R. G. R. (2018). *Assessment of hydrogeological conditions using resistivity data: A case study in Moragahakanda area, Sri Lanka.* In *PGIS Research Congress of University of Peradeniya, Science* (Vol. 14).

Akbari, V., Rajabi, M. A., Chavoshi, S. H., & Shams, R. (2008). *Landfill site selection by combining GIS and fuzzy multi-criteria decision analysis: A case study of Bandar Abbas, Iran. World Applied Sciences Journal*, 3(Suppl. 1), 39–47.

Annepu, R. (2012). *Sustainable solid waste management in India.* Columbia University. https://www.nswai.org/docs/Sustainable%20Solid%20Waste%20Management%20in%20India_Final.pdf

BC Ministry of Environment. (2016). *Landfill criteria for municipal solid waste* (2nd ed.). https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/landfill_criteria.pdf

Davidson, G. (2011). *Waste management practices: Literature review.* Dalhousie University. https://cdn.dal.ca/content/dam/dalhousie/pdf/dept/sustainability/resources/publications-and-plans/waste/Waste%20Management%20Literature%20Review%20Final%20June%202011%20(1.49%20MB).pdf

Dissanayake, P., Hettiarachchi, S., & Siriwardana, C. (2018). *Increase in disaster risk due to inefficient environmental management, land use policies and relocation policies: Case studies from Sri Lanka. Procedia Engineering*, 212, 1326–1333. https://doi.org/10.1016/j.proeng.2018.01.171

Ejaz, N., Akhtar, N., Nisar, H., & Naeem, U. A. (2010). *Environmental impacts of improper solid waste management in developing countries: A case study of Rawalpindi City. Sustainable World*, 142, 379–387. https://doi.org/10.2495/sw100351

Ferronato, N., & Torretta, V. (2019). *Waste mismanagement in developing countries: A review of global issues. International Journal of Environmental Research and Public Health*, 16(6), 1060. https://doi.org/10.3390/ijerph16061060

Ijjasz-Vasquez, E., Wahba, S., & Kaza, S. (2018). *Here's what everyone should know about waste. World Bank Blogs.* https://blogs.worldbank.org/sustainablecities/heres-what-everyone-should-know-about-waste

Jayasinghe, R. (2015). *A critical study of the wastescape in the Western Province of Sri Lanka: Pathways towards alternative approaches.* https://api.research-repository.uwa.edu.au/ws/portalfiles/portal/8153738

Jayasinghe, R., & Baillie, C. (2014). *Waste, power and justice: Towards a socially and environmentally just waste management system in Sri Lanka.* Brill. https://brill.com/display/book/9781848882928/BP000006.xml

Kharat, M. G., Kamble, S. J., Raut, R. D., & Kamble, S. S. (2016). *Identification and evaluation of landfill site selection criteria using a hybrid fuzzy Delphi, fuzzy AHP and DEMATEL based approach. Modeling Earth Systems and Environment*, 2(2). https://doi.org/10.1007/s40808-016-0171-1

Lamond, J., Bhattacharya, N., & Bloch, R. (2012). *The role of solid waste management as a response to urban flood risk in developing countries, a case study analysis. Flood Recovery, Innovation and Response III.* https://doi.org/10.2495/friar120161

Landfill Solutions. (2021). *Did you know? In 2050, the world will generate 3.4 billion tonnes of waste per year.* https://landfillsolutions.eu/did-you-know-the-world-will-generate-3-4-billion-tonnes-of-waste-per-year-in-2050

Lavigne, F., et al. (2014). *The 21 February 2005, catastrophic waste avalanche at Leuwigajah dumpsite, Bandung, Indonesia. Geoenvironmental Disasters*, 1(1). https://doi.org/10.1186/s40677-014-0010-5

Lohri, C. R., Camenzind, E. J., & Zurbrügg, C. (2014). *Financial sustainability in municipal solid waste management – Costs and revenues in Bahir Dar, Ethiopia. Waste Management*, 34(2), 542–552. https://doi.org/10.1016/j.wasman.2013.10.014

Magutu, P. O., & Onsongo, C. O. (2011). *Operationalising municipal solid waste management.* IntechOpen. https://www.intechopen.com/chapters/18477

Maheshi, D., Steven, V. P., & Karel, A. (2015). *Environmental and economic assessment of 'open waste dump' mining in Sri Lanka. Resources, Conservation & Recycling*, 102, 67–79. https://doi.org/10.1016/j.resconrec.2015.07.004

Majid, M., & Mir, B. A. (2021). *Landfill site selection using GIS based multi-criteria evaluation technique: A case study of Srinagar city, India. Environmental Challenges*, 3, 100031. https://doi.org/10.1016/j.envc.2021.100031

Martuzzi, M., Mitis, F., & Forastiere, F. (2010). *Inequalities, inequities, environmental justice in waste management and health. European Journal of Public Health*, 20(1), 21–26. https://doi.org/10.1093/eurpub/ckp216

Mussa, A., & Suryabhagavan, K. V. (2019). *Solid waste dumping site selection using GIS-based multi-criteria spatial modeling: A case study in Logia town, Afar region, Ethiopia. Geology, Ecology, and Landscapes.* https://doi.org/10.1080/24749508.2019.1703311

Nascimento, V. F., Sobral, A. C., Andrade, P. R., Yesiller, N., & Pierre, J. (2017). *Natural disaster risk in municipal solid waste disposal sites using GIS: A case study in São Paulo State, Brazil. Journal of Water Resource Protection*, 9(11), 1213–1224. https://doi.org/10.4236/jwarp.2017.911079

National Building Research Organisation. (2017). *Disastrous failure at the solid waste disposal site at Meethotamulla.* https://nbro.gov.lk/index.php?option=com_content&view=article&id=110

National Building Research Organisation. (2017). *Geotechnical assessment on the failure at Meethotamulla waste fill.* https://www.nbro.gov.lk/images/special_projects/Geotechnical-Assessment-on-The-Failure-at-Meethotamulla-Waste-Fill.pdf

Quitzow, R., Libo, W., & Jacob, K. (2012). *Green jobs in Asia: Achievements, strategies and*

potentials. Universität Berlin. https://library.fes.de/pdf-files/iez/10387.pdf

Ramachandra, T. V. (2009). *Management of municipal solid waste.* TERI.

Rouse, J. R. R. (2006). *Seeking common ground for people: Livelihoods, governance and waste. Habitat International*, 30(4), 741–753. https://doi.org/10.1016/j.habitatint.2005.09.001

Sefouhi, L., Kalla, M., & Bahmed, L. (2014). *Assessment of different methods of treatment for an integrated municipal waste management for an Algerian city. Management of Environmental Quality: An International Journal*, 25(4), 493–504. https://doi.org/10.1108/meq-01-2013-0008

Simon, A. (2008). *Analysis of activities of community-based organizations involved in solid waste management: Investigating modernized mixtures approach* (MSc Thesis, Wageningen University). https://edepot.wur.nl/183894

Sugirtharan, M., & Rajendran, M. (2015). *Ground water quality near municipal solid waste dumping site at Thirupperumthurai, Batticaloa. Journal of Agricultural Science*, 10(1), 21. https://doi.org/10.4038/jas.v10i1.8044

The World Bank. (2023). *Trends in solid waste management.* https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html

UNDRR. (2015). *Disaster.* https://www.undrr.org/terminology/disaster

United States Environmental Protection Agency. (2022). *Criteria for solid waste disposal facilities: A guide for owners/operators.* https://www.epa.gov/landfills/criteria-solid-waste-disposal-facilities-guide-ownersoperators

USAID. (2011). *Introduction to disaster risk reduction* (pp. 1–59). https://www.preventionweb.net/files/26081_kp1concepdisasterrisk1.pdf

Vidanaarachchi, C. K., Yuen, S. T. S., & Pilapitiya, S. (2006). *Municipal solid waste management in the Southern Province of Sri Lanka: Problems, issues and challenges. Waste Management*, 26(8), 920–930. https://doi.org/10.1016/j.wasman.2005.09.013

Visvanathan, C., & Tränkler, J. (2003). *Municipal solid waste management in Asia – A comparative analysis.* In *Workshop on Sustainable Landfill Management* (pp. 3–15). https://www.researchgate.net/publication/242220878

Wong, J. W. C., Surampalli, R. Y., Zhang, T. C., Tyagi, R. D., & Selvam, A. (Eds.). (2016). *Sustainable solid waste management.* https://doi.org/10.1061/9780784414101

Yahaya, N. S., Choun-Sian, L., Taha, M. R., & Pereira, J. J. (2016). *Exposure of municipal solid waste disposal sites to climate related geohazards: Case study of Selangor. Bulletin of the Geological Society of Malaysia*, 62, 57–63. https://doi.org/10.7186/bgsm62201608

Zurbrügg, C. (2002). *Urban solid waste management in low-income countries of Asia: How to cope with the garbage crisis. SCOPE Conference Proceedings*, 1–13. https://www.researchgate.net/publication/228735642

Ziraba, A. K., Haregu, T. N., & Mberu, B. (2016). *A review and framework for understanding the potential impact of poor solid waste management on health in developing countries. Archives of Public Health*, 74(1). https://doi.org/10.1186/s13690-016-0166-4

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GIS MODEL TO FORECAST PHYTOPLANKTON DISTRIBUTION TO IDENTIFY BEST FISHING SITES: A CASE STUDY FROM EXCLUSIVE ECONOMIC ZONE, SRI LANKA

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As per the declaration of United Nation's Convention on the Law of the Sea (UNCLOS) Sri Lanka claims sovereign rights over an Exclusive Economic Zone (EEZ) that is approximately eight times the size of its land area. According to the guides of UNCLOS, a state that own an EEZ asserts the right for exploring, exploiting, conserving and managing natural resources including either living and non-living found in sea bed, water column and sub soil. Consequently, the marine fisheries play a crucial role in the national economy and serve as a significant source of food supply in Sri Lanka. The industry provides both direct and indirect employment to approximately 560,000 individuals and supports the livelihoods of over 2.7 million coastal residents. According to the official records, the fisheries sector accounted for 1.3% of the country's Gross Domestic Product (GDP). In another way it contributes more than 60% of the nation's animal protein intake.

Based on the spatial distribution of Sri Lanka's EEZ, three distinct fishing zones have been identified, categorized according to their distance from the coastline. These are: the Coastal Fishery Zone, extending up to 40 km (25 miles) from the shore, the Offshore Fishery Zone, located between 40 km and 161 km (25 to 100 miles) from the coast, the Deep-Sea Fishery Zone, which extends beyond 161 km (100 miles) from the coastal baseline up-to the outer boundary of the EEZ.

According to an initial comprehensive survey conducted during 1979–1980, coastal fisheries were estimated to yield an annual catch of approximately 250,000 tons, with a further 90,000 to 150,000 tons potentially harvestable from the remainder of the EEZ. However, recent statistics from 2017 to 2020 indicate that coastal fisheries continue to be the dominant sub-sector, contributing 57% of the country's total marine fish production, with a cumulative catch of 933,880 tons. In comparison, offshore and deep-sea fisheries collectively accounted for 697,350

tons, representing 43% of the total marine catch during the mentioned period.

Despite being a significant contributor to the national economy and a significant source of food, Sri Lanka's marine fishery sector faces considerable uncertainty due to annual fluctuations in fish harvests. This variability is primarily attributed to the absence of an effective system for identifying optimal fishing grounds at different times of the year. Data from the period 2008–2021 reveal substantial variation in total fish yields across the fifteen fishery districts around the island. Notably, the same data also indicate a clear growth in various aspects of the sector, including the number of employees, motorized and modern fishing vessels, fishing technologies, storage capacities, ice room facilities, financial support, and other related infrastructure. Therefore, this variability in fish yields cannot be attributed to a lack of resources or infrastructure but rather to the challenge of accurately locating the areas of fish concentration throughout the year.

Even though there are in-situ observation devices such as Sonar Fish Finders, the lack of a scientific and practical method to forecast fishing sites distribution on a temporal basis across the entire EEZ poses significant challenges. Accordingly, fishermen may miss optimal fishing locations or waste time and resources searching for them, leading to inefficiencies in meeting the demands of the fishing industry. In that case, the study leads to solve the issue of how optimal fishing sites can be identified, in different times of an upcoming year to increase the fishery harvest and improve the reliability of yield.

Among the major factors that influencing fish concentration, climate change-particularly the rise in sea surface temperature (SST) comprise both direct and indirect effects on global fish production. As global temperatures increase, the spatial distribution of fish stocks tends to shift in search of more favorable environmental conditions. It is well established that fish generally concentrate in regions with suitable temperatures. Additionally, phytoplankton, as the foundational component of the marine food web, plays a vital role in attracting zooplankton and subsequently higher trophic organisms, including fish. Areas with high phytoplankton concentrations are therefore more likely to support abundant fish populations. Consequently, temperature and food availability are two key factors that influence the formation of productive fishing grounds. Building on this understanding, the study proposed that phytoplankton abundance serves as a core indicator for identifying potential fishing zones. Accordingly, it has determined that, by forecasting the temporal distribution of phytoplankton, it is possible to forecast optimal fishing sites across the EEZ.

To accomplish the target set above, the study defined several objectives. The primary objective was to develop a GIS-based phytoplankton forecasting model to identify optimal fishing sites within Sri Lanka’s EEZ by analyzing historical trends in phytoplankton abundance. As a form of micro flora, phytoplankton contain chlorophyll pigments, which can be detected through optical satellite sensors. The specially designed sensors and algorithms that useful for marine observation, is capable of studying several marine parameters. These include chlorophyll concentration, SST, phytoplankton carbon concentration, sea ice extent, ocean color and more. This capability has been systematically utilized to conduct the study.

Satellite images often contain cloud patches that result in missing data, which can compromise the accuracy of analysis unless effectively addressed. Therefore, as the second objective, a methodology has been developed to overcome the issue of cloud-covered areas in satellite imagery and mitigate the 'no data' error.

The third objective was to evaluate the applicability and effectiveness of remote sensing (RS) technology in marine sector studies. Given the vastness of the marine environment and the inherent limitations of manual and in-situ observations such as natural constraints, economic costs, and time consumption, RS presents a practical alternative for large-scale marine monitoring.

Overall, the study aimed to provide a sustainable and practical solution to address the limitations of

existing marine fishing site identification methods, which currently rely solely on in-situ observation tools and personal instincts, both of which lack the capability for temporal forecasting.

Methodology

Satellite-derived ocean color imagery enables the estimation of marine phytoplankton levels by measuring how sunlight is reflected from the ocean surface across specific wavelengths, particularly within the 400–600 nanometer (nm) range, which has strong water penetration capability. Phytoplankton pigments such as chlorophyll-a absorb more blue light and reflect more green light, and thus the ratio of blue-to-green water-leaving radiance serves as a quantitative indicator of biomass. This reflectance ratio is processed through a calibrated polynomial algorithm to estimate chlorophyll-a concentrations. In this study, this capability was used to establish a sufficient historical record of phytoplankton abundance, and subsequently, an appropriate projection technique was applied to generate future scenarios. The projected data were then compared with actual data from an overlapping time period, and because the projection closely matched the actual statics, consistently showing a positive correlation, the methodology for phytoplankton estimation and projection was validated as suitable for future forecasting.

Results and Discussion

While following developed research methodology, the forecasted outcomes were validated against actual data. Upon verification, a 100% positive correlation was found between actual and forecast data, confirming its effectiveness as a reliable approach for phytoplankton forecasting.

Once finalized the method with such verification, using a decade of historical satellite images from 2007 to 2017, the monthly distribution of chlorophyll for the year 2022 was derived. The results indicate that the majority of chlorophyll was concentrated in the coastal fishery sub-zone, whereas the offshore zone exhibited moderate concentrations, and the deep-sea zone recorded consistently lower levels throughout the year. (Fig. 1). The forecast is further supported by fish yield records from the years 2020, 2021, and 2022, which show that approximately 54% of the yield was obtained from the coastal sub-zone, while the offshore and deep-sea zones together accounted for the remaining 46%. Accordingly, the forecast also supports the established understanding that areas with higher concentrations of primary food sources (phytoplankton) tend to correspondingly support greater accumulations of tropical species.

The accumulation of more phytoplankton within coastal sub zone is a result of up-welling process which brings cold, nutrient-rich water from the deep ocean to the surface, particularly in shallow waters. This make shallow waters to generate nutrient-rich environment to support the growth of seaweed and phytoplankton and consequently attract fish schools. Also, the phytoplankton typically circulate vertically due to irradiance and flow horizontally with ocean currents and significantly concentrates in shallows. However, the ability of satellite imaging to detect the depth of a water column is limited up to 20 m depending on several factors including illuminate of the sun.

The marine biological findings note that, even the photic zone leads usually up to 200 m average, majority of the total phytoplankton biomass is concentrated within a narrow depth range of 10–15 m, where effective photosynthesis occurs. Moreover, out of 41 primary phytoplankton species, only eight—including several dinoflagellates and coccolithophore species, primarily survive in deeper waters only during the warmer seasons. Accordingly, the use of RS to forecast phytoplankton volume appears to be an effective approach. As an example, the comparison between actual and forecasted chlorophyll levels for September 2022 (Figure 2) demonstrates the success of the study by revealing a similar pattern in chlorophyll distribution.

In the forecast, the amount of phytoplankton is represented by the chlorophyll concentration, in mg/m^3. Chlorophyll, as an indicator of photosynthetic pigments, reflects the volume of

phytoplankton present in the water. The monthly spatial distribution of phytoplankton can be publicly distributed in an appropriate format, allowing stakeholders to easily identify relevant coordinates.

Apart to the fisheries sector, the findings can also be utilized in other marine based activities, such as whale watching, algae harvesting, and similar pursuits. These forecasts are important for understanding the global carbon cycle, as phytoplankton play a key role in carbon fixation through photosynthesis. Accurate predictions help improve climate models and track ecosystem health in a changing ocean. In addition, forecasting phytoplankton distribution supports a wide range of scientific research and assists policymakers in developing marine environmental management strategies. Such forecasts also provide governments and conservation agencies with essential data to guide climate change adaptation, monitor marine protected areas, and respond proactively to ecosystem imbalances.

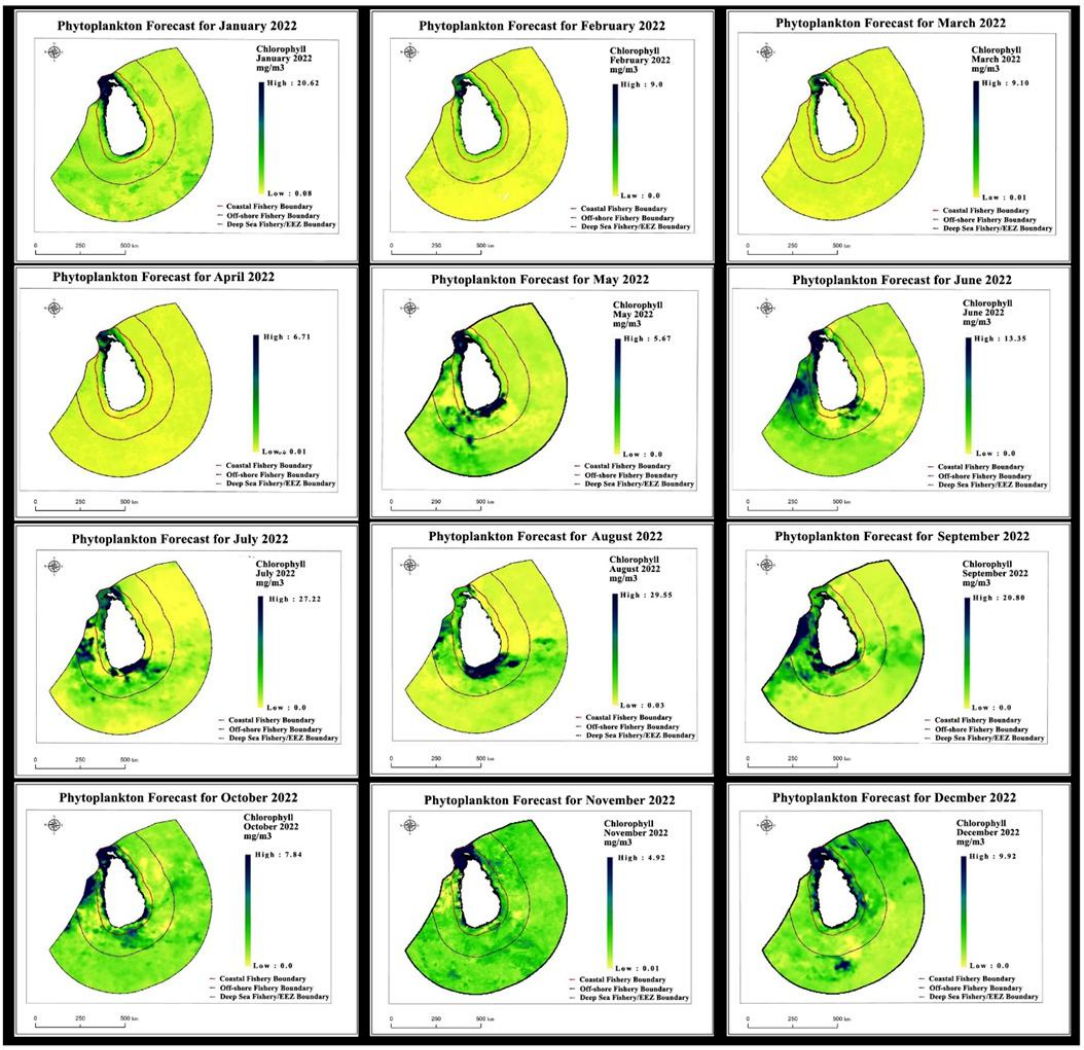

Figure 1. Month wise forecasted phytoplankton distribution within EEZ of Sri Lanka for the year 2022, referring to the chlorophyll distribution from 2007-2017

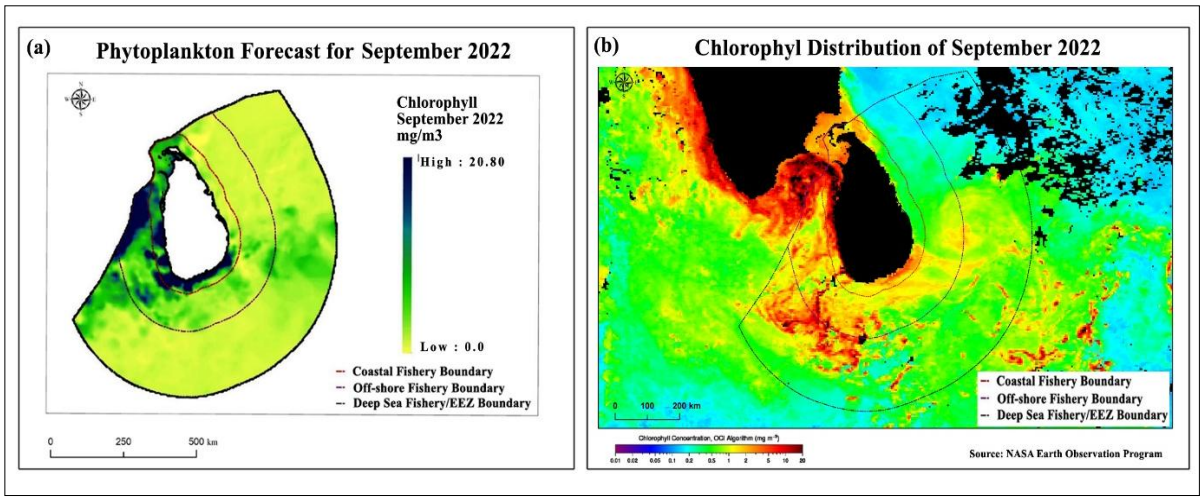

Figure 2. Comparison of actual vs forecasted chlorophyll values (a) Forecasted chlorophyll distribution within EEZ of Sri Lanka in September, 2022 (b) Actual distribution of chlorophyll within EEZ of Sri Lanka in September, 2022

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Selected References

Bimal, P. M., Sasmita, M., Janendra, S., & Anil, P. S. (2010). *Climate change: Impacts on fisheries and aquaculture* (1st ed.). InTechOpen.

Doeramann, L. (2024). How satellites are mapping the ocean floor without getting wet. *Science Tech Daily.* https://www.sciencetechdaily.com/ocean-floor-mapping

Joseph, L. (1984). 200 miles exclusive economic zone and fishery development in Sri Lanka. *Journal of the National Aquatic Resources Research and Development Agency of Sri Lanka, 31*, 51–56.

Rutledge, K., McDaniel, M., Teng, S., Hall, H., Ramroop, T., Sprout, E., Hunt, J., Boudreau, D., & Costa, H. (2024). *Upwelling*. *National Geographic Encyclopedia*. https://education.nationalgeographic.org/resource/upwelling

Thesis reference

Wickramasinghe, W. A. R. (2025) GIS model to forecast phytoplankton distribution to identify best fishing sites: a case study from Exclusive Economic Zone, Sri Lanka. MSc Thesis, Postgraduate Institute of Science, University of Peradeniya.

Institution where research was carried out

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MICROPLASTIC AND THEIR CHARACTERIZATION IN THREE SPECIES OF MOLLUSKS IN SELECTED COASTAL SITES IN THE WESTERN PROVINCE, SRI LANKA

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Microplastics (MPs), defined as plastic particles less than 5 mm in diameter, have emerged as pervasive and persistent pollutants in marine ecosystems worldwide. These particles can originate from the degradation of larger plastic items (secondary microplastics) or can be manufactured at small sizes (primary microplastics) for use in various commercial products. Once released into the environment, they accumulate in marine food webs and pose significant risks to aquatic life and, potentially, to human health.

Sri Lanka's Western Province, with its dense urbanization, industrial zones, fishing activity, and tourism, is especially susceptible to microplastic pollution. Mollusks, due to their filter-feeding and grazing behavior, are particularly vulnerable to ingesting microplastics, making them useful bioindicators of environmental contamination. This study investigates the concentration, morphology, and polymer composition of microplastics found in three mollusk species collected from six strategically selected coastal sites in the Western Province of Sri Lanka.

The objectives of this study were to quantify the presence of microplastics in *Saccostrea* sp. (Rock Oyster), *Littorina* sp. (Periwinkle), and *Patella* sp. (Limpet) collected from six coastal sites in the Western Province of Sri Lanka. The study also aimed to evaluate spatial differences in microplastic concentrations across these sites. Additionally, it sought to identify the morphological types and polymer composition of the extracted microplastics using microscopy and Fourier Transform Infrared Spectroscopy (FTIR). Finally, the research assessed the suitability of the selected mollusk species as bioindicators for monitoring coastal microplastic pollution.

Methodology

This study was conducted from August 2021 to July 2022 across six coastal sites representing varying degrees of human activity: Galle Face, Negombo, Sarakkuwa, Dehiwala, Panadura, and Beruwela. Mollusks were collected during low tides using standard ecological sampling techniques. Specimens of *Saccostrea* sp., *Littorina* sp., and *Patella* sp. were selected based on their abundance and habitat coverage.

Tissue samples were chemically digested using 10% KOH at 60 °C for 48 h. The resulting digestate was filtered, and potential microplastic particles were identified using visual inspection under a stereomicroscope (Figure 1) and confirmed with a hot needle test. FTIR was used to determine the polymer types of selected particles by matching their spectral signatures with known plastic standards. Data analysis was performed using one-way ANOVA to compare microplastic concentrations between sites for each species.

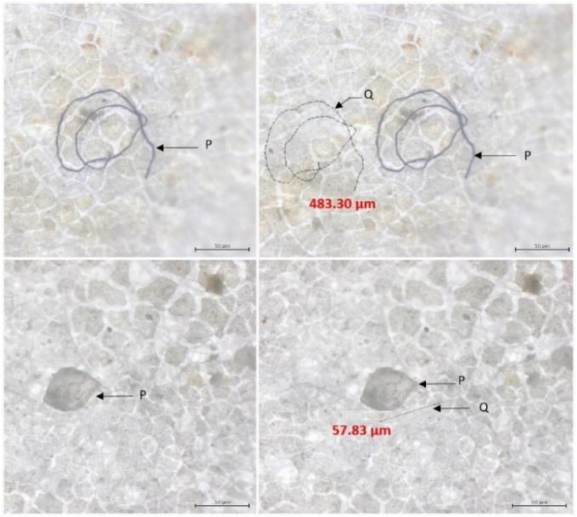

Figure 1. (P) MP particles, (Q) Measuring MP plastic length using ToupView software.

Results and Discussion

Microplastics were detected in all mollusk samples, indicating widespread contamination along the Western Province coastline. Saccostrea sp. (Table 1) and Littorina sp. (Table 2) exhibited significant variation in microplastic accumulation across sites ($p = 0.001$), with Galle Face showing the highest concentration levels: 6.51±1.51 MPs/g in Saccostrea sp. and 3.77±2.2 MPs/g in Littorina sp. In contrast, Patella sp. (Table 3) showed no significant differences among sites ($p = 0.350$), with concentrations remaining relatively consistent (e.g., 2.77 MPs/g at Galle Face vs. 2.10 MPs/g at Panadura).

Different types and colors of microplastic particles were identified under the photomicroscope in the studied molluscan species samples (Figure 2.). All observed particles were documented at a scale bar of 50 µm.

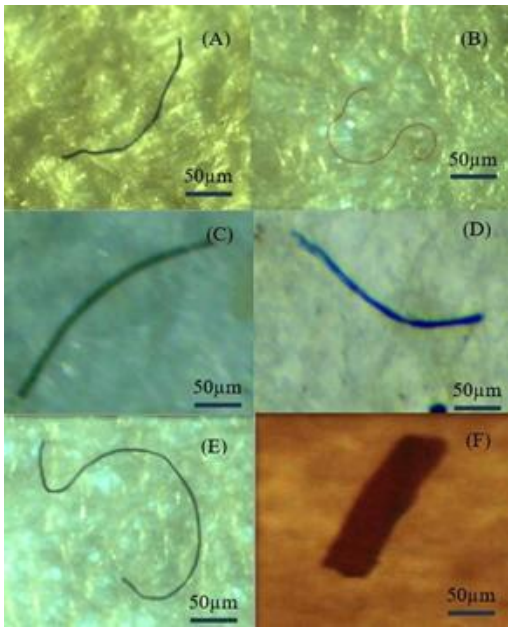

Figure 2. Different types and colors of images of (a) Black filaments, (b) Red filament, (c) Green fragment, (d) Blue filament, (e) blue filament), (f) Brown rod, type of identified under Photomicroscope in studied Species samples

Table 1. Microplastic concentration (MPs/g) in *Saccostrea* sp. across six study sites over the designated time period

Period	Location					
	Negombo	Sarakkuwa	Gall Face	Dehiwela	Panadura	Beruwela
August- October	2.74± 0.45	5.06±1.26	6.51±1.51	5.69±0.77	4.41±0.80	3.53±1.01
November- January	2.60±0.55	2.63±1.28	4.16±1.17	4.97±0.66	4.76±0.79	2.64±1.23
February- April	2.00±0.77	3.28±1.29	3.03±1.66	3.84±0.82	5.03±0.85	3.37±1.18
May- July	3.09±1.48	5.11±2.20	5.37±1.68	5.00±0.71	6.24±0.88	5.04±0.68

Table 2. Microplastic concentration (MPs/g) in Littorina sp. across six study sites over the designated time period

Period	Location					
	Negombo	Sarakkuwa	Galle Face	Dehiwela	Panadura	Beruwela
August - September	2.89± 0.33	2.33±0.37	4.80±1.26	2.08±0.85	1.44±0.78	1.96±0.64
November- January	2.34± 0.21	1.68±0.44	2.67±1.29	1.72±1.00	1.21±0.92	3.35±0.35
February April	2.11±0.30	2.50±0.11	2.70±1.57	3.65±1.02	2.90±1.05	3.25±0.39
May- July	2.54±1.09	2.35±0.25	4.92±1.36	2.21±1.27	1.42±2.53	2.70±2.34

Table 3. Microplastic concentration (MPs/g) in Patella sp. across six study sites over the designated time period

Period	Location					
	Negombo	Sarakkuwa	Galle Face	Dehiwela	Panadura	Beruwela
August- October	1.76±0.33	2.65±0.32	4.83±1.38	2.35±5.95	1.89±0.19	2.83±0.70
November- January	2.01±0.25	2.10±0.38	2.16±0.10	1.17±6.98	2.04±0.15	1.97±0.76
February -April	2.49±0.12	2.70±0.07	2.12±0.11	3.83±1.77	2.14±0.14	1.56±1.04
May- July	2.33±0.20	2.80±1.58	1.97±0.25	2.43±1.06	2.34±0.21	3.03±1.66

The predominant microplastic type was filamentous (62.45%), followed by fragmented particles (17.64%) and film-like fragments (12.98%). Blue was the most frequently observed color (43.84%), typically associated with textile fibers or fishing gear. FTIR analysis confirmed the presence of polymers(Figure 3) such as polypropylene (PP), polyvinyl chloride (PVC), and polyethylene (PE), indicating sources from packaging materials, fishing equipment, and domestic waste.

These findings highlight the influence of human activity and pollution sources on microplastic levels in marine environments. The higher concentrations at urbanized beaches such as Galle Face and Negombo suggest point-source contamination from stormwater runoff, sewage discharges, and recreational activities. The significant bioaccumulation in Saccostrea sp. and Littorina sp. further supports their utility as sentinel species for microplastic monitoring programs.

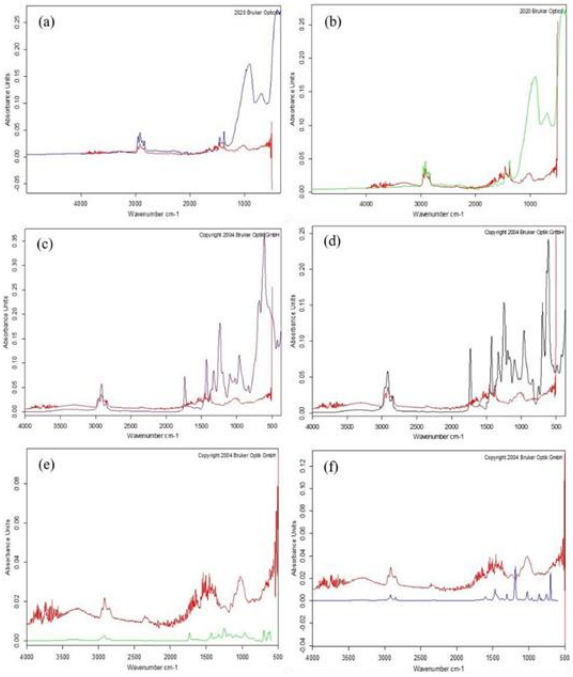

Figure 3. FTIR spectra of analyzed MPs in species

(a) PP identified by filaments (blue and red), fragments (blue and red) and others in Negombo, (b) PP identified by filaments (blue and red) in Sarakkuwa, (c) PVC- Hard identified by filaments (blue and red) in Galle Face, (d) Polyvinyl Chloride-Un plasticized (PVC-U) identified by filaments (blue and red) in Dehiwela, (e) PVC-U identified by fragments (blue and red), and others in Panadura, (f) Polyphenylene Ether + High Impact Polystyrene identified by fragments (blue and red) in Beruwela.

Conclusion

This study provides crucial baseline data on microplastic contamination in mollusks along Sri Lanka's western coast. The findings confirm the widespread presence of microplastics in intertidal mollusks and highlight spatial differences influenced by local environmental and anthropogenic factors. The data support the use of *Saccostrea* sp., *Patella* sp. and *Littorina* sp. as effective bioindicators and call for urgent interventions in plastic waste management and pollution mitigation. Strategies such as improved waste collection, public education, and stricter regulations on plastic use are essential to reduce microplastic pollution in these ecologically and economically important coastal areas.

Selected References

Athawuda, N., Senevirathna, J. D., & Amarasekara, T. H. (2020). Plastic debris distribution in selected beaches along the west coast of Sri Lanka. *Marine Pollution Bulletin, 160*, 111575. https://doi.org/10.1016/j.marpolbul.2020.111575

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science, 347*(6223), 768–771. https://doi.org/10.1126/science.1260352

Jayasiri, H., Purushothaman, C., & Vennila, A. (2013). Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India. *Environmental Monitoring and Assessment, 185*, 7709–7719. https://doi.org/10.1007/s10661-013-3151-9

Kumara, P. B. T. P., Jayathilaka, B. N., & Priyadarshana, T. (2023). Microplastics in coastal and marine environments of Sri Lanka: A review of sources, impacts, and management strategies. *Marine Pollution Bulletin, 185*, 114267. https://doi.org/10.1016/j.marpolbul.2022.114267

Thushari, G. G. N., Chavanich, S., Yakupitiyage, A., & Senevirathna, J. D. M. (2017). Effects of microplastic on sessile invertebrates in the eastern coast of Thailand: An approach to coastal zone conservation. *Marine Pollution Bulletin, 116*(1–2), 121–129. https://doi.org/10.1016/j.marpolbul.2017.01.005

Wijethunga, S., Rathnayake, H., Karunathilake, N., Perera, K., & Thushari, G. G. N. (2023). Microplastic contamination in commercially important marine species from the southwest coast of Sri Lanka. *Environmental Pollution, 296*, 118770. https://doi.org/10.1016/j.envpol.2022.118770

Publications

Wijethunga, P. (2025). Microplastic accumulation in *Saccostrea cucullata* along Sri Lanka's west coastal belt: Implications for seafood safety policy recommendations. *Proceedings of the International Conference on Fisheries and Aquaculture, 11*(1), 36–56. https://doi.org/10.17501/23861282.2024.11103

Thesis reference

Wijethunga, H. N. S. (2025). Microplastic and their characterization in three species of mollusks in selected coastal sites in the Western Province, Sri Lanka (Master's thesis). Postgraduate Institute of Science, University of Peradeniya.

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FEXTENSION OF THE APPLICABILITY OF METHOD OF DIRECTLY DEFINING THE INVERSE MAPPING FOR PARTIAL DIFFERENTIAL EQUATIONS AND MATHEMATICAL MODELS FOR FINGERING PHENOMENON IN OIL INDUSTRY

Dr. Chathuri Weeragunarathna Sahabandu *is a Confirmed Lecturer in the Department of Mathematics, Faculty of Natural Sciences, The Open University of Sri Lanka, since 2022. Chathuri earned her B.Sc. (Hons) Special Degree in Mathematics from the University of Peradeniya in 2019, graduating with First Class Honours. She was placed on the Dean's List and received a University Award for Academic Excellence in recognition of her outstanding academic performance. She was awarded the 1st runner-up in the Three Minute Thesis (3MT) competition organized by The Open University of Sri Lanka in 2023 based on her Ph.D. work. She completed her Ph.D. in Mathematics in 2024, at the young age of 29, at the Postgraduate Institute of Science, University of Peradeniya.*

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Her doctoral research focused on advanced semi-analytical and numerical methods for solving nonlinear partial differential equations (PDEs), particularly using the recently developed Method of Directly Defining the inverse Mapping (MDDiM). Originally introduced by Liao in 2016 for solving nonlinear ordinary differential equations, MDDiM offers a novel approach by enabling the direct definition of inverse linear mappings, thus eliminating the need to compute the inverse of operators explicitly. She extended this technique to systems of nonlinear PDEs, including fuzzy PDEs, using numerical analysis via Maple 16.

This work not only provides theoretical extensions to MDDiM but also demonstrates its applicability to real-world phenomena. She has solved various physical systems such as harmonic wave propagation and heat-like equations, using MDDiM, and developed complex models on fingering patterns observed in oil recovery processes. These studies explore diverse initial and boundary conditions and identify optimal inverse mappings to ensure accurate approximation within minimal computational time. This work further constructed mathematical models for miscible and immiscible viscous fingering under enhanced oil recovery (EOR) conditions, incorporating practical parameters such as fluid injection types, gravitational effects, mass flow variations, and magnetic field influences. EOR techniques, including thermal, chemical, and flooding methods, have been employed to boost oil production, while recent advancements explore the use of miscibility and magnetic fields to enhance efficiency.

Methodology

Her modeling focuses on developing mathematical models to increase injection fluid saturation within the considered domain, thereby enhancing oil recovery while stabilizing the

displacement front and reducing irregular fingering patterns.

$$\frac{\partial S_i}{\partial T}+\frac{\partial}{\partial X}\left(S_i\frac{\partial S_i}{\partial X}\right)+A\sin\alpha\frac{\partial}{\partial X}(S_iX)-B\frac{\partial}{\partial X}S_i-C=0 \quad (1)$$

where $A=\frac{L^2\mu\lambda^2}{4\pi\beta}$ and $B=\frac{(\rho_i-\rho_n)gL}{\beta}$, $C=\frac{\mu_n L^2K_0}{K\beta}\left({k_{eq}}^2-1\right)$ with the initial condition, $S_i(X,0)=0.01X^2$ Equation (1) gives the governing equation of fingero-imbibition phenomenon when magnetic field present for miscible fingers.

Results and Discussion

Figure 1 illustrates the results obtained from solving equation (1) using Maple 16 with the MDDiM approach.

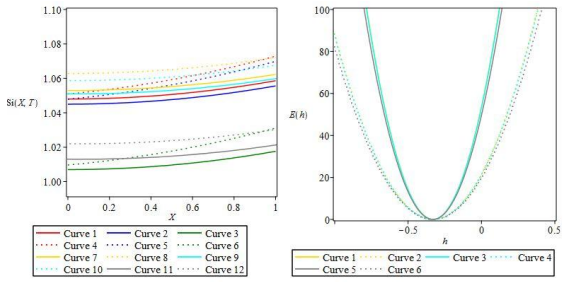

Figure 1. Saturation of nanofluid $S_i(X,T)$ versus distance X for fixed value of time $T=1$ (left) and corresponding error graphs (right). (Solid and dash lines represent inclination angles $\alpha=0^0$ and $\alpha=10^0$ and Al_2O_3-red and yellow, SiO_2-blue and cyan, and MgO-green and gray, and curves 1-6 without magnetic field, curves 7-12 presence of magnetic field represent respectively)

In addition to numerical methods, this study employed COMSOL Multiphysics 5.6 to simulate viscous fingering in a 2-D Darcian homogeneous porous medium. Simulations analyzed critical parameters including log-mobility ratios, injection speeds, mixing lengths, and finger dynamics.

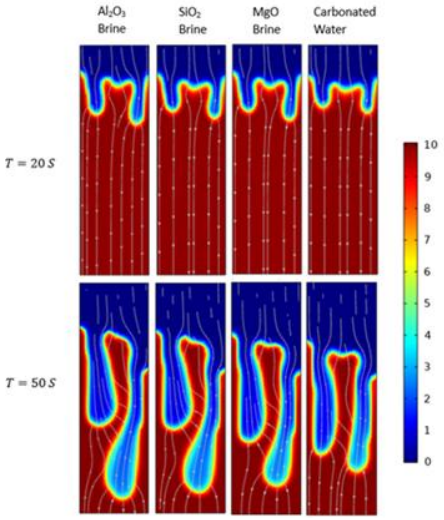

Figure 2. Spatio-temporal evaluation of fingers using COMSOL for different miscible injections

Conclusion

The results show strong agreement with experimental findings, reinforcing the reliability and versatility of the numerical framework. These studies significantly enhance the toolkit available for scientists and engineers to tackle nonlinear PDEs and fluid dynamics problems, particularly in the context of energy and environmental applications.

Selected References

Baxter, M., Dewasurendra, M., & Vajravelu, K. (2017). A method of directly defining the inverse mapping for solutions of coupled systems of nonlinear differential equations. *Numerical Algorithms, 77*(4), 1199–1211. https://doi.org/10.1007/s11075-017-0359-0

Choksi, B., & Singh, T. R. (2019). A mathematical model of imbibition phenomenon in homogeneous porous media. *Special Topics & Reviews in Porous Media, 10*(1), 1–13. https://doi.org/10.1615/SpecialTopicsRevPorousMedia.20

Dewasurendra, M., Baxter, M., & Vajravelu, K. (2018). A method of directly defining the inverse mapping for fourth order non-linear systems arising in combined free and forced convection in

a second grade fluid. *Applied Mathematics and Computation, 339*, 758–767. https://doi.org/10.1016/j.amc.2018.07.015

Liao, S., & Zhao, Y. (2016). On the method of directly defining inverse mapping for nonlinear differential equations. *Numerical Algorithms, 72*(4), 989–1020. https://doi.org/10.1007/s11075-015-0077-4

Singh, A., Pandey, K. M., & Singh, Y. (2021). Numerical investigation of immiscible liquid–liquid displacement in Hele-Shaw cell. *Materials Today: Proceedings, 45*, 7151–7155. https://doi.org/10.1016/j.matpr.2021.02.151

Publications

Karunarathna, W. H. D. T., Sahabandu, C. W., & Dewasurendra, M. (2021, October 8–9). Semi-analytic solutions for the transitional Korteweg–de Vries equation via similarity solutions. *In Proceedings of the International Conference on Mathematics and Mathematics Education* (Abstract ID: 21, p. 16).

Sahabandu, C. W., Dewasurendra, M., & Juman, Z. A. M. S. (2021, October 8–9). An extension to the method of directly defining the inverse mapping for propagation of harmonic waves in nonlinear generalized magneto-thermoelasticity with two relaxation times under influence of rotations. *In Proceedings of the International Conference on Mathematics and Mathematics Education* (Abstract ID: 18, p. 13).

Sahabandu, C. W., Dewasurendra, M., & Juman, Z. A. M. S. (2021, December 21–22). Mathematical modelling and MDDiM solutions for fingering phenomenon during the nano silica flooding. *In Proceedings of the ISymRU 2021, Mathematics, Statistics and Data Science* (p. 112).

Sahabandu, C. W., Dewasurendra, M. (2021, October 29–31). Mathematical modellings for fingering phenomenon of incline oil layers with and without considering the mass flow rates and their solutions using the method of directly defining the inverse mapping. *In Proceedings of the Postgraduate Institute of Science Research Congress (RESCON 2021)* (Abstract ID: 99 – ICT, Mathematics and Statistics, p. 59).

Sahabandu, C. W., Dewasurendra, M. (2022, January 19). MDDiM solutions for the mathematical modeling of fingering phenomenon in oil industry during the carbonate–water injection. *In Proceedings of the 9th Ruhuna International Science and Technology Conference (RISTCON 2022)* (p. 47). University of Ruhuna, Matara, Sri Lanka. ISSN 1391-8796.

Sahabandu, C. W., Dewasurendra, M. (2022, October 29–30). Enhanced oil recovery using one-dimensional nanoparticles. *In Proceedings of the Postgraduate Institute of Science Research Congress (RESCON 2022)* (Abstract ID: 75 – ICT, Mathematics and Statistics, p. 70).

Sahabandu, C. W., Dewasurendra, M. (2023, July 14–15). Mathematical modelling for fingero-imbibition during carbonated water flooding with magnetic field effect. *In Proceedings of the International Conference on Mathematics and Mathematics Education* (Abstract ID: 4, p. 4).

Sahabandu, C. W., Dewasurendra, M. (2023, July 14–15). MDDiM solutions in solving nonlinear fuzzy heat-like equations. *In Proceedings of the International Conference on Mathematics and Mathematics Education* (Abstract ID: 5, p. 5).

Sahabandu, C. W., Dewasurendra, M. (2023, September 20–21). Choice of the inverse linear operator in the method of directly defining the inverse mapping for inhomogeneous heat and advection problems. *In Proceedings of Peradeniya University International Research Sessions 2023* (Vol. 24, Abstract ID: 178, p. 213). Sri Lanka.

Sahabandu, C. W., Dewasurendra, M. (2023, November 10). Mathematical modelling for fingero-imbibition phenomenon: Influence of the magnetic field during different nano floodings. *In Proceedings of the Open University Research Sessions (OURS 2023)* (p. 158). The Open University of Sri Lanka. ISSN 2012-9912.

Sahabandu, C. W., Dewasurendra, M. (2023, November 24). On the choice of the inverse linear mapping in the method of directly defining the inverse mapping for nonlinear partial differential equations. *In Proceedings of the Annual International Conference on Business Innovation (ICOBI)* (pp. 22–30).

Sahabandu, C. W., Dewasurendra, M. (2024, January 24). CFD simulation for miscible and immiscible viscous fingering formation for distinct injective fluids. *In Proceedings of the 11th Ruhuna International Science & Technology Conference (RISTCON 2024)* (p. 61). University of Ruhuna, Matara, Sri Lanka. ISSN 1391-8796.

Sahabandu, C. W., Dewasurendra, M. (2024). *COMSOL Multiphysics: CFD simulations of miscible and immiscible fingering instability in enhanced oil recovery.* In *Proceedings of the International Conference on Computational and Mathematical Modelling 2024* (pp. 170–176).

Sahabandu, C. W., Dewasurendra, M. (2024). Method of directly defining the inverse mapping for nonlinear fuzzy heat-like partial differential equations. *Ceylon Journal of Science, 53*(1), 133–138. https://doi.org/10.4038/cjs.v53i1.8197

Sahabandu, C. W., Dewasurendra, M. (2024). Modelling and semi-analytical solutions for fingering instability during zero-dimensional nanofloodings. *Ceylon Journal of Science, 53*(4), 631–638. https://doi.org/10.4038/cjs.v53i4.8321

Sahabandu, C. W., Dewasurendra, M., Juman, Z. A. M. S., Vajravelu, K., & Chamkha, A. J. (2022). Semi-analytical method for propagation of harmonic waves in nonlinear magneto-thermoelasticity. *Computers & Mathematics with Applications, 105,* 107–111. https://doi.org/10.1016/j.camwa.2021.11.020

Sahabandu, C. W., Juman, Z. A. M. S., Vajravelu, K., Spangler, B., & Dewasurendra, M. (2025). Modeling and semi-analytical solution for immiscible and miscible fingers formation during enhanced oil recovery. *International Journal of Modelling and Simulation*, Taylor & Francis, 0228-6203. VOL. 45, NO. 5, 1584–1595. https://doi.org/10.1080/02286203.2023.2296369

Sahabandu, C. W., Karunarathna, D., Sewvandi, P., Juman, Z. A. M. S., Dewasurendra, M., & Vajravelu, K. (2021). A method of directly defining the inverse mapping for a nonlinear partial differential equation and for systems of nonlinear partial differential equations. *Computational and Applied Mathematics, 40*(6), 1–16. https://doi.org/10.1007/s40314-021-01627-y

Sahabandu, C. W., Karunarathna, W. H. D. T., & Dewasurendra, M. (2021, February 17). Application of the method of directly defining the inverse mapping to fingering phenomenon in the oil industry. *In Proceedings of the 8th Ruhuna International Science and Technology Conference (RISTCON 2021)* (p. 59). University of Ruhuna, Matara, Sri Lanka. ISSN 1391-8796.

Thesis reference

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REPRODUCTIVE PERFORMANCES AND BLOOD METABOLIC PROFILE CHANGES IN SEVERELY EMACIATED POST-PARTUM CROSSBRED DAIRY COWS AFTER INTRODUCING AN IMPROVED FEEDING REGIMEN

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Transition cow management can determine the future production success of individual cows. The peripartum period (3-4 weeks before parturition) and early postpartum period (3-4 weeks after parturition) are known as the transition period of cows.

During the first few weeks of early lactation, dry matter intake is decreased and milk production is increased. Therefore, the energy demand is greater than the amount of energy consumed. This will lead to mobilization of body reserves and loss of weight. This is known as a negative energy balance (NEB). However, cows cannot ingest a sufficient amount of energy-yielding feed from voluntary dry matter intake to meet the energy requirement after calving.

Analysis of blood metabolites is useful to detect the mobilization of adipose tissue and protein catabolism during negative energy balance. It is also helpful to get an idea about subsequent rebreeding performance. Cows undergo a state of negative energy balance and thus extensively metabolize body reserves which is indicated by increased serum Non-Esterified Fatty Acids (NEFA) and Beta hydroxy Butyric Acid (BHBA) contents.

The onset of lactation creates a very high demand for calcium. It results sudden drop of blood calcium level at calving and leads to milk fever. Lower blood calcium levels and negative Dietary Cation-Anion Difference (DCAD) activate bone resorption until the digestive tract gains the ability of calcium absorption. To overcome this condition, a sufficient amount of calcium should be added to the close-up diet at least 14 days before calving.

The period of ovarian inactivity in a postpartum cow is extended due to inadequate feeding of cows. This happens due to a suppression of the pulsatile release of Leuteinizing Hormone (LH) from the anterior pituitary gland [10]. The release of GnRH from the hypothalamus is controlled by LH. Gonadotropin Releasing Hormone (GnRH) acts on the ovaries and causes cycling and ovum maturing. Blood-borne metabolites such as NEFA and BHBA that are made due to direct consequences of NEB, negatively affect on quality, viability and function of oocytes and corpus luteum.

Therefore, the proposed study was aimed to assess the potential of improving the Body Condition Score (BCS), metabolic profile and reproductive performance of severely emaciated *Bos taurus* crossbred dairy cows at post-partum through provision of an improved ration.

Methodology

Approval of the Ethical Review Committee of the Faculty of Veterinary Medicine and Animal Science, University of Peradeniya was obtained to conduct the experiment (VERC-20-06). The experiment was conducted at the Veterinary Teaching Farm of the Department of Farm Animal Production and Health, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, from 10th October 2020.

Twenty *Bos taurus* crossbred (Friesian x Jersey) dairy cows at the third parity were randomly selected from the dairy cattle herd reared at Bound Dairies Farm, Matale and Agro Dairies Farm, Mawathagama. These cows had been imported from New Zealand during the second trimester of their first parity by the government of Sri Lanka. It appears that the cows had been neglected and poorly fed. At present, they were severely emaciated and the BCS was around 1 and all animals were at the post-partum stage. The selected cows were transported to the Veterinary Teaching Farm and housed in a well-ventilated open shed with cemented concrete floor covered with rubber bedding material. During the period of the experiment, all cows were fed ad libitum with a mixed ration including mixed grass, commercial concentrates, bypass fat and vitamin and mineral pre-mixture. Additionally, the cows were allowed free access to clean fresh drinking water.

Feed analysis was performed at the Veterinary Research Institute, Gannoruwa, Sri Lanka and the blood metabolic profile was analysed at the Faculty of Animal Science, the University of Peradeniya, Sri Lanka.

Special attention was paid to the changes in the intake. The body weight and BCS of the cows were recorded at the commencement of the experiment (day one), at 14 days and thereafter at 30-day intervals until the pregnancy of the cow is confirmed. Additionally, the status of both ovaries (Flat/ Round) and uterus (Normal/ Abnormal) were examined per-rectally and using ultrasound scan images. (LNADWIND P09, linear transducer).

When the cows reached 2.5 BCS and the diameter of at least one of the ovaries was greater than 2.5 cm, the cows were synchronized following the Ovsynch protocol. In the protocol, the first dose of GnRH, PGF2α and the second dose of GnRH were administered intramuscularly (IM) at day 1, day 7 and day 9, respectively. After

20 hours from administration of the second dose of GnRH the cows were artificially inseminated using deep frozen semen. On the 40th day from the insemination, the pregnancy statuses of the cows were diagnosed using an ultrasound scan image. The same Ovsynch protocol was repeated twice for non-pregnant cows.

Blood samples (3 mL) were collected through the coccygeal vein of the experimental cows into sterile syringes (10 mL disposable medical grade plastic syringes with 21G x 1 1/2" needle, ethylene oxide sterilization and compiles to ISO 11135:2019)) at the commencement of the experiment (Day one), at day 14 and thereafter at 30-day intervals until the pregnancy was confirmed. Within 5 hour of blood sample collection, they were centrifuged (Labnet Hermle Z300 Micro Centrifuger) for 15 minutes at 4000 g and serum was collected into micro-centrifuge tubes and stored at -20°C until analysed for serum metabolites.

The serum samples were thawed at room temperature and analyzed for NEFA (Cat. No. FA 115), BHBA (Cat. No. RB 1008), Albumin (Cat. No. AB 362), Calcium 135 (Cat. No. CA 2390) and Phosphorous (Cat. No. PH 1016) contents using commercial biochemical test kits (Randox Laboratories Ltd., United Kingdom) and serum auto analyzer (3000 Evolution®, 136 Biochemical System International, Arezzo, Italy).

The association among the BW, BCS, serum metabolic profile and reproductive performance in response to improved feeding regimen was assessed through Pearson's correlation coefficient. Differences in the investigated parameters during the study period were statistically analyzed through Analysis of Variance (ANOVA). Mean separation was done through Dunkan's Multiple Range Test (DMRT). Further, the means of serum metabolites were compared with upper and lower critical limits (reference range) of serum metabolites for Boss taurus crossbred dairy cows for identification of the status of negative energy balance.

Results and Discussion

The chemical composition and in vitro digestibility parameters of mixed grass and concentrate feed are presented in Table 1.

Table 1. Nutrient percentages and Metabolic Energy of improved feeding regimen

Nutritive value	Mixed Grass	Concentrate Feed
Dry Matter (DM %)	19.59	95.76
Total mineral content (Ash %)	10.63	11.85
Crude Protein (CP %)	8.95	15.5
Organic Matter Digestibility (OMD %)	29.54	35.23
Metabolic Energy (ME MJ kg^{-1} DM)	4.55	5.01
Nutritive value of final mixed ration: CP - 10.04 %, ME - 4.67 MJ kg^{-1} DM		

Higher DM% and lower CP% of the given mixed grass sample revealed its high NDF and ADF content. "Reference [3] reported that the NDF and ADF percentages were 71.6 ± 4.3 and 38.4 ± 3.7 respectively when DM% was 18.8 ± 0.9 and CP% was 8.8 ± 0.7 for CO3 grasses. Therefore, Higher DM% (19.59) and lower CP% (8.95) of the experimental mixed grass sample revealed its high NDF and ADF content. The higher NDF levels (>70% DM) of the forage indicated its lower quality and resulted in low DMI during the postpartum period [5]. Therefore, these cows did not meet their nutritional requirements solely with a forage diet; hence it was balanced by adding concentrate feed. Though the experimental animals were in their postpartum period, they were not pregnant and neither lactating, therefore, these animals only required energy for maintenance.

Recorded body weight indicates that the mean weight value increases from 392 kg to 459 kg

with the improved feeding regimen. The maintenance energy requirement of dairy cattle at this weight range is lies between 45 – 50 MJ. The energy acquired through mixed grass and concentrate was 71.49 MJ. Therefore, the supplied feed during the study period was enough to fulfil the animal's energy requirement. CP% of concentrate feed was 15.5 % and this helps animals to fulfil the balance of protein which was not sufficiently taken from forage. Body weight gain and the commencement of reproduction during the study period revealed that the given feeding regimen was sufficient to meet the energy and protein requirements of animals.

Table 2: Response of severely emaciated Boss taurus crossbred dairy cows at post-partum for improved feeding regimen

Parameter	Days from commencing the improved feeding regimen															P value
	Day 1*†			Day 14*†			Day 30*†			Day 60*†			Day 90*†			
Body weight (kg)	392		4.33d	409	±	4.60c	430	±	4.48b	451	±	5.07a	459	±	4.97a	$p < 0.05$
BCS	1.05	±	0.03d	1.50	±	0.05c	1.98	±	0.07b	2.50	±	0.07a	2.55	±	0.05a	$p < 0.05$
NEFA (mmol L^{-1})	0.57	±	0.05a	0.38	±	0.02b	0.28	±	0.05c	0.24	±	0.02c	0.20	±	0.01c	$p < 0.05$
BHBA (mmol L^{-1})	0.04	±	0.01c	0.35	±	0.06a	0.46	±	0.06a	0.22	±	0.04b	0.39	±	0.03a	$p < 0.05$
Albumin (g dL^{-1})	2.02	±	0.12a	2.06	±	0.09a	2.14	±	0.09a	1.61	±	0.11b	0.97	±	0.06c	$p < 0.05$
P (mg L^{-1})	12.45	±	2.61a	8.65	±	1.07a	11.05	±	0.83a	8.54	±	0.71a	10.68	±	1.20a	$p > 0.05$
Ca (mg L^{-1})	3.73	±	0.97bc	2.59	±	0.82c	5.06	±	0.66ab	6.02	±	0.77ab	7.39	±	0.68a	$p < 0.05$

*, Mean ± SE. †, Means followed by different superscripts are significantly different ($p < 0.05$).

Physiological parameters of Body weight and BCS were gradually increased ($p < 0.05$) from Day 1 to Day 90 and both parameters significantly differed ($p < 0.05$) between Day 1 to Day 60 and not thereafter. This is attributed to an improved feeding regimen from day 01 which facilitates weight gain of the dairy cows.

NEFA concentration was gradually decreased ($p < 0.05$) with an improved feeding regimen. NEFA values were significantly ($p < 0.05$) different from day 1 to day 30 and not thereafter. NEFA concentration at day 1 (0.57 ± 0.05a mmol L-1) exceeded the upper critical limit (0.52 mmol L-1) of the NEFA reference range. That indicated the postpartum cows were in negative energy balance. NEFA concentration between day 14 to day 90 was within the reference range which revealed the animal's energy balance was back to normal with an improved feeding regimen.

There was an association ($p < 0.05$) between BHBA concentration and improved feeding regimen according to the obtained results.

Albumin concentration was increased from day 1 to day 30 and it did not show a significant difference during day 1 to day 30. After day 30, Albumin concentration was gradually decreased. Albumin concentration was significantly different ($p < 0.05$) from day 30 to day 90. Albumin content remained below the lower limit of the reference range throughout the study period. Albumin concentrations decreased at calving and remained at a low level up to 2 weeks and also this might be associated with a low protein diet. These cows were malnourished before taking into the test.

Calcium concentration was gradually increased ($p < 0.05$) with an improved feeding regimen. Calcium concentration was not significantly different between day 1 & day 14 and between

day 30 & day 60. However, calcium concentration was significantly different ($p < 0.05$) from day 1 to day 90. Calcium concentration was gradually increased and remained within the reference range at the end of the study period. Those changes might be associated with Ca supplementation.

Throughout the study period, phosphorous concentration exceeded the upper critical limit of the phosphorus reference range. That might be associated with excessive Phosphorus supplementation. There was no significant difference ($p > 0.05$) in values from day 1 to day 90.

Table 3: Reference range of serum metabolites of Boss taurus dairy cows for identification of status of negative energy balance.

Metabolite	Critical limits for *Boss taurus* crossbred cows	
	Lower limit	Upper limit
NEFA (mmol L^{-1})	0.01	0.52[1]
BHBA (mmol L^{-1})	0.30	1.50[1]
Albumin (g dL^{-1})	2.80	3.90[4]
Ca (mg L^{-1})	7.00	11.00[5]
P (mg L^{-1})	4.30	8.00[3]

Right ovarian thickness was gradually increased ($p < 0.05$) from Day 1 to Day 60 and parameters significantly differed ($p < 0.05$) between day 1 to day 30 and not thereafter. Left ovarian thickness was gradually increased ($p < 0.05$) from Day 1 to Day 60 and parameters significantly differed ($p < 0.05$) between day 14 to day 60 and not thereafter. Cycling signs of cows gradually increased ($p < 0.05$) from Day 1 to Day 60 and parameters significantly differed ($p < 0.05$) between day 1 to day 30 and not thereafter. This is attributed to improved feeding regimens can improve the ovarian thickness and reproductive performance of dairy cows.

Metabolic compounds that are released when changing the nutritional status of the animal can act on the hypothalamic-pituitary-ovarian axis. These metabolic signals that are induced via supplementation of different nutrient components affect the reproduction of the animal.

Table 4: Conception status after improved feeding regimen of AI cows

No. of days taken for conception after the first AI	40	80	125	Non-pregnant after 125 days
No. of conceptions	12	5	2	1
Percentage of conception (%)	60	85	95	

The conception rate of the cows was 60% after the first AI and 95% of cows got pregnant at 125 days after the 3rd AI (Table 4). This indicates that improved feeding to postpartum malnourished cows has a positive effect on conception.

Conclusion

This is attributed to an improved feeding regimen facilitating weight gain, BCS improvement, and commencement of reproductive performance and conception of the dairy cows.

Selected References

Adrien, M. L., Mattiauda, D. A., Artegoitia, V., Carriquiry, M., Motta, G., Bentancur, O., & Meikle, A. (2012). Nutritional regulation of body condition score at the initiation of the transition period in primiparous and multiparous dairy cows under grazing conditions: Milk production, resumption of post-partum ovarian cyclicity and metabolic parameters. *Animal, 6*(2), 292–299.

Drackley, J. K., & Cardoso, F. C. (2014). Prepartum and postpartum nutritional management to optimize fertility in high-yielding dairy cows in confined TMR systems. *Animal*, 9 April, 5–14.

Duffield, T. F., & Leblanc, S. J. (2009). Interpretation of serum metabolic parameters around the transition period. In *Proceedings of the Southwest Nutrition and Management Conference Online* (pp. 106–114).

Kahn, C. M., & Line, S. (2011). *Merck veterinary manual* (10th ed.). Whitehouse Station, NJ: Merck & Co.

Kumara, S. N., Parkinson, T. J., Laven, R. A., Waghorn, G. C., Pushpakumara, A., & Donaghy, D. J. (2022). Nutritional investigation of major feed types and feed rations used in medium-scale dairy production systems in Sri Lanka. *Animals, 12*(18), 2391. https://doi.org/10.3390/ani12182391

Lager, K., & Jordan, E. (2012). The metabolic profile for the modern transition dairy cow. In *Proceedings of the mid-south ruminant nutrition conference 2012* (pp. 9–16). Grapevine, TX, USA: Texas A&M University.

PennState Extension. (2017). Metabolic profiling of transition cows: Can we predict impending problems? http://extension.psu.edu/animals/health/metaboliprofiling/bibliography/metabolic-profiling-of-transition-cows-can-we-predict-impending-problems [Accessed 12 August 2022]

Puls, R. (1989). *Mineral levels in animal health: Diagnostic data: Minerals in animal nutrition* (2nd ed.). Clearbrook, BC, Canada: Sherpa International.

Ranaweera, K. K. T. N., Mahipala, M. B. P. K., & Weerasinghe, W. M. P. B. (2020). Evaluation of energy balance in tropical and temperate crossbred dairy cows at post-partum transition stage: A case study. *Tropical Agricultural Research, 31*(2), 12–20.

Randel, R. D. (1990). Nutrition and postpartum rebreeding in cattle. *Journal of Animal Science, 68*(3), 853–862. https://doi.org/10.2527/1990.683853x [Accessed December 2023]

Rowlands, G. J., Manston, R., Stark, A. J., Russell, A. M., Collis, K. A., & Collis, S. C. (1980). Changes in albumin, globulin, glucose and cholesterol concentrations in the blood of dairy cows in late pregnancy and early lactation and relationships with subsequent fertility. *The Journal of Agricultural Science, 94*(3), 517–527.

Thelaksan, T., Chathurika, W. V. A., Weerasinghe, W. M. P. B., & Mahipala, M. B. P. K. (2018). Identification and assessment of nutritive value of widely used feedstuffs for dairy cattle during Yala season in Vavuniya and Mullaitivu districts of Northern Province, Sri Lanka. In *Proceedings of the Jaffna University International Research Conference, 27th September 2018* (pp. 27–30). University of Jaffna.

Weerathunga, D., Udagama, D., Campbell, S., Barber, D., & Weerasinghe, P. (2023). Performance of the Napier hybrid cultivars CO-5 (Pennisetum glaucum × P. purpureum schumach) and Sampoorna (Pennisetum pedicillatum × P. americanum) harvested at five intervals. *Grasses, 2*(3), 156–167. https://doi.org/10.3390/grasses2030013 [Accessed January 2023]

Publications

Ariyarathna, H. M. H. S., Perera, D. P., Lenagala, A. S., Chathurangani, Y., & Jayapani, V. P. P. (2015). Pathological hemocysts in the tricuspid valve of a crossbred pup. Presented at the 67th Annual Scientific Sessions of the Sri Lanka Veterinary Association (SLVA), 76.

Ariyarathna, H. M. H. S., Piyadasa, T. M. S. K., Atapattu, A. M. U., Bulumulla, D. G. S. S., de Silva, M. L. W. P., Lenagala, A. S., Uyanwatta, P. N., Edirimanne, E. R. K. V., Jayasinghe, M. G. C. M., Kumara, W. R. B., Indrajith, R. A. D. E., Adikari, A. M. R. B., Silva, I. D., & De Silva, D. D. N. (2017, May). Prognostic relevance of cytological grades and subtypes of lymphomas (using the updated Kiel's classification) in forty cases of canine lymphomas. Presented at the 69th Annual Scientific Sessions of the Sri Lanka Veterinary Association (SLVA), 5.

De Silva, S., Rajapaksha, A. S., & Cebuliak, E. L. (2016). Use of bees honey and cinnamon oil combination in treating necrotic wounds in dogs and cats. Presented at the 68th Annual Scientific Sessions of the Sri Lanka Veterinary Association (SLVA), 55.

Dissanayake, D. R. K., Silva, I. D., De Silva Senapathi, Y. U., Sumanasekara, K. K., Kumara, W. R. B., Dunukearachchi, P. M., Fernando, W. R. C., Lenagala, A. S., & De Silva, S. (2016). The prognostic significance of blood leukocyte counts at the onset of hemorrhagic diarrhea in parvoviral enteritis among immunized pups. Presented at the 68th Annual Scientific Sessions of the Sri Lanka Veterinary Association (SLVA), 35.

Lenagala, A. S., Ariyarathna, H. M. H. S., & De Silva, D. D. N. (2016). Accuracy of diagnostic cytology using impression smears in the evaluation of cutaneous and subcutaneous masses from dogs. Presented at the 68th Annual Scientific Sessions of the Sri Lanka Veterinary Association (SLVA), 34.

Lenagala, A. S., & Samarasundara, S. A. A. P. (2024). Impact of management practices on milk production efficiency in a selected group of dairy farms in Sri Lanka. Presented at the 76th Annual Scientific Sessions of the Sri Lanka Veterinary Association (SLVA).

Lenagala, A. S., Nizanantha, K., Alexander, B. D., Weerasinghe, W. M. P. B., & Kumara Mahipala, M. B. P. (2024, August). The effect of improved ration on body condition, metabolic profile, and reproductive performance in severely emaciated crossbred dairy cows. Proceedings of PURSE, University of Peradeniya, 25, 230.

Thesis reference

Lenagala, A. S. (2025). The effect of improved ration on body condition, metabolic profile, and reproductive performance in severely emaciated crossbred dairy cows. MSc Thesis, Post Graduate Institute of Science, University of Peradeniya.

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STUDY ON URINARY BIOMARKERS AND URINE MICROBIOME IN A COHORT OF DIABETIC AND HYPERTENSIVE CHRONIC KIDNEY DISEASE PATIENTS IN SRI LANKA

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The global burden of chronic kidney disease (CKD) is increasing substantially, with a high mortality rate. Over the last three decades, data revealed that CKD has emerged as the leading cause of death worldwide and accounts for 1.2. million deaths worldwide in 2017, it is expected to rise to 4.0 million by 2040. Moreover, impaired renal failure has been one of the top ten causative factors for death and disability in Sri Lanka. In 2017, 4512 deaths were reported in Sri Lanka due to CKD.

Though the life expectancy in the South Asian population is higher than in other countries, people suffering from Non-Communicable Disease (NCD) have become a burden to them as they live longer with diseases and disabilities. Diabetes mellitus is the leading metabolic risk factor for CKD resulting in more than ten million cases worldwide in recent years. Hypertension is another risk factor for developing CKD.

Serum creatinine, a choice of renal marker currently used in many clinical settings, indicates the overall functional state of glomeruli. However, serum creatinine is also influenced by

several factors other than kidney function. Histological examination is a gold standard method for the diagnosis of diabetic kidney disease. Therefore, there is a need to develop non-invasive diagnostic biomarkers for early and differential diagnosis of diabetic and hypertensive chronic kidney disease.

This study explores differentially expressed genes within a proposed gene panel to establish their potential as biomarkers for distinguishing diabetic and hypertensive nephropathy from other causes of CKD. While clinical practice currently relies on biomarkers such as serum creatinine and albuminuria for diagnosis of CKD, the ability to differentiate CKD based on aetiology primarily depends on histological examinations, especially kidney biopsies. Although kidney biopsies are considered the gold standard for confirming CKD diagnosis, there is a need to develop non-invasive diagnostic methods for CKD subtyping. This study primarily concentrates on developing urinary biomarkers for diabetic and hypertensive nephropathy. The study employs gene expression analysis using the relative quantification method of RT-qPCR to identify specific biomarkers for disease diagnosis. Furthermore, Urine dysbiosis is another causative factor for gene dysregulation. Therefore, early diagnosis and therapeutic approaches require identifying reliable and sensitive biomarkers and elucidating the urine microbiome profiles in relation to the aetiological causes and gene dysregulation.

Methodology

Ethical clearance was obtained from the Committee for Ethical Clearance (CEC) of the Postgraduate Institute of Science (PGIS), University of Peradeniya in November 2020. A total of 155 (gene expression analysis n = 115; urine microbiome study n = 40) samples were included in this study. Urine samples were obtained from both CKD patients attending the Nephrology clinic, District General Hospital, Vavuniya and Healthy volunteers.

CKD patients were recruited as diabetic nephropathy (DN), hypertensive nephropathy (HN), CKD patients with both diabetes and hypertension (HD) and CKD with other etiological causes (CKD-O). Total RNA was extracted from centrifuged urine deposit using guanidium thiocyanate phenol-chloroform RNA extraction method. The quantity and integrity of extracted RNA were assessed using Quantifluor ST fluorometer and 1% non-denaturing agarose gel electrophoresis. The extracted RNA was subjected to cDNA synthesis using the commercial Reverse Transcription kit according to the manufacturer's guidelines. The gene panel to be studied was selected from the findings of the previous study of our laboratory (unpublished data). The primers were designed using the National Center for Biotechnology Information (NCBI) primer blast software using exon-exon spanning.

qPCR reaction of each primer was optimized using the inhibition plot analysis and the efficiency of each primer were calculated. All the primers that showed acceptable efficiency were used for further analysis. In such way the genes such as Neutrophil gelatinase associated lipocalin (*NGAL*), Annexin (*ANXA3*), Olfactomedin 4 (*OLFM4*), Peptidase inhibitor 3 (*PI3*), Matrix metalloproteinase 9 (*MMP9*), and Protein methyl transferase 3 (*PRMT3*) against the reference gene, ß-2 Microglobulin (*B2M*) were included in this study. The gene expression was analyzed using relative quantification method. Study genes and their dysregulations in both HC and CKD study groups were analyzed separately.

Results and Discussion

The results indicated that *ANXA3*, *OLFM4*, *PI3* and *MMP9* could be used as a potential biomarker for CKD diagnosis. (Figure 1). The correlation analysis showed that certain genes among the above panel could be used as potential diagnostic biomarkers for early disease diagnosis. Among the studied genes, *NGAL,* a gene potentially responsible for tubular injury could serve as an early diagnostic biomarker for diabetic nephropathy and need further analysis like proteomic studies for clinical implementation. It means that measuring the urine NGAL protein level and establishing the cut-off level of individual biomarkers in urine specimens would be more valuable for clinical implementation.

NGAL consistently binds to the MMP9 and prolongs the MMP9 activity. Previous studies proved a positive correlation between the *NGAL* and *MMP9* expression in diabetic kidney injury. Conversely, the present study revealed a contrast in findings in this context and needs further understanding by analysing the influencing factors especially the presence of urobiome and its influence in gene dysregulation.

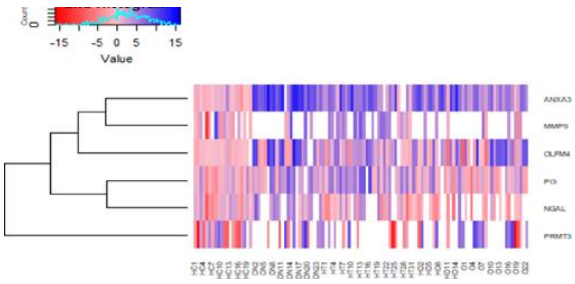

Figure 1. The heatmap and the dendrogram of individual samples for each studied gene. The Log 2 normalized fold -changes were used to express the gene expression. The colour intensity in the heatmap demonstrated the relative expression levels of study genes, with brighter blue colours indicating higher upregulations and brighter red expressions, representing lower expression or downregulations.

Notably, the *PRMT3* gene showed a statistically significant negative correlation with serum creatinine while showing a strong positive correlation with eGFR. In contrast with the hypertensive nephropathy study group, diabetic nephropathy patients showed a negative correlation with eGFR.

Additionally, our current study compares bacterial diversity and microbial load using both culture-based and high throughput NGS techniques in kidney disease patients, and the results were compared with healthy control samples to elucidate the urine dysbiosis in diabetic and hypertensive nephropathy. Genomic DNA was extracted from the urine sediment. The extracted DNA was subjected for 16S rRNA bacterial metagenomic analysis. This metagenomic analysis was performed using the commercial facility at Macrogen Inc., South Korea. Firstly, the quality control of the DNA sample was performed using the absorbance at A260/A280. The DNA library was prepared by tagmentation of DNA samples. It allows the DNA fragmentation and tag the DNA with adapter sequences. Then, the adapter ligated DNA fragments were amplified using the 16S V3-V4 universal primer sequences. After preparation of the DNA library, the libraries were pooled and sequenced on MiSeq 300 bp, PE; 30% Phi X (Illumina, USA) according to the protocol at Macrogen In., Korea. The 16S rRNA metagenomic analysis of the raw sequences was performed using the Mouthr pipeline with the Galaxy interface.

Both techniques revealed consistent core findings, indicating that CKD patients exhibit significantly higher bacterial diversity with relatively high abundance. However, the culture-based method yielded only 12 bacterial genera from the samples in this study population. In contrast, the NGS approach identified more than two hundred bacterial genera within the same study cohort. Figure 2 shows the Operational Taxonomic Unit (OUT) of the study population.

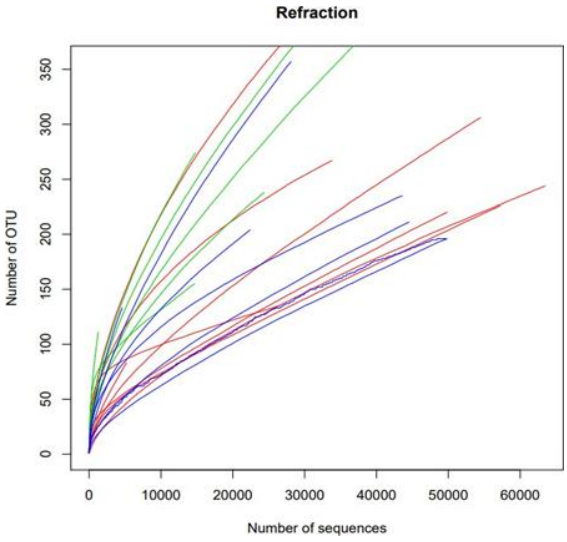

Figure 2. Operational Taxonomic Unit (OTU) Refraction Curve of 20 Samples in HC (blue), DN (red), and HT (green) groups

Several factors contribute to this discrepancy. Firstly, abundant bacterial species in the culture-based method might overshadow the detection of rare and low- abundance species. Secondly, the growth of certain bacteria may lead to the

production of metabolites that inhibit the growth of other bacterial species. These inhibitory processes may contribute to the limited identification of bacterial diversity using traditional culture-based techniques, emphasizing the need for high-throughput methods like NGS to capture the full spectrum of microbial communities in complex environments such as the urinary microbiome.

The increased diversity index in early CKD to late CKD stages (irrespective of the aetiology of CKD) in our study indicates an increase in microbial diversity as CKD progresses. This rise in diversity suggests a potential alteration in the urinary microbiome composition associated with advancing CKD. This study indicates a more similar diversity of bacterial community among the study groups (Figure 3).

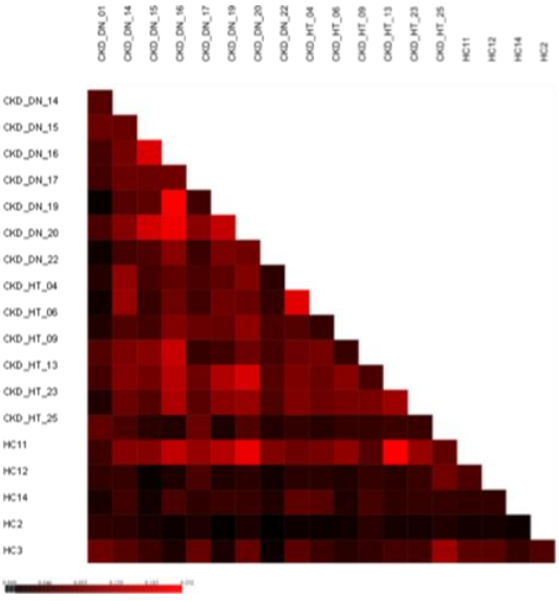

Figure 3. The heatmap compares the beta diversity) between different study samples. The red colours indicate bacterial communities that are more similar compared to the black colour.

Conclusion

In summary, the findings of this study suggest that the *ANXA3* gene could serve as a non-invasive screening biomarker for CKD. Additionally, NGAL and OLFM4 are indicative of early detection in diabetic nephropathy. The integration of urine microbiota research with transcriptional analysis holds promise in providing a comprehensive understanding of microbial colonization in the bladder and urinary system among CKD patients. This integration can aid in elucidating their presence in the regulation of mRNA expression among CKD patients which potentially contributing to the development of biomarkers.

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Selected References

Arambewela, M. H., Somasundaram, N. P., Jayasekara, H. B. P. R., Kumbukage, M. P., Jayasena, P. M. S., Chandrasekara, C. M. P. H., Fernando, K. R. A. S., & Kusumsiri, D. P. (2018). Prevalence of chronic complications, their risk factors, and the cardiovascular risk factors among patients with type 2 diabetes attending the diabetic clinic at a tertiary care hospital in Sri Lanka. *Journal of Diabetes Research, 2018,* Article 2018.

Bikbov, B., Purcell, C. A., Levey, A. S., Smith, M., Abdoli, A., Abebe, M., Adebayo, O. M., Afarideh, M., Agarwal, S. K., Agudelo-Botero, M., & Ahmadian, E. (2020). Global, regional, and national burden of chronic kidney disease, 1990–2017: A systematic analysis.

Greco, M., Chiefari, E., Mirabelli, M., Salatino, A., Tocci, V., Cianfrone, P., Foti, D. P., & Brunetti, A. (2022). Plasma or urine neutrophil gelatinase-associated lipocalin (NGAL): Which is better at detecting chronic kidney damage in type 2 diabetes? *Endocrines, 3*(2), 175–186.

Jayalath, S., & Magana-Arachchi, D. (2022). Dysbiosis of the human urinary microbiome and its association to diseases affecting the urinary system. *Indian Journal of Microbiology*, 1–14.

Kramer, H., Kuffel, G., Thomas-White, K., Wolfe, A. J., Vellanki, K., Leehey, D. J., Bansal, V. K., Brubaker, L., Flanigan, R., Koval, J., & Wadhwa, A. (2018). Diversity of the midstream urine microbiome in adults with chronic kidney disease. *International Urology and Nephrology, 50*, 1123–1130. https://doi.org/10.1007/s11255-018-1860-7

Levin, A., Stevens, P. E., Bilous, R. W., Coresh, J., De Francisco, A. L., De Jong, P. E., & Winearls, C. G. (2013). KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney International Supplements, 3*(1), 1–150. https://doi.org/10.1038/kisup.2012.73

Meisel, J. S., Sfyroera, G., Bartow-McKenney, C., Gimblet, C., Bugayev, J., Horwinski, J., Kim, B., Brestoff, J. R., Tyldsley, A. S., Zheng, Q., & Hodkinson, B. P. (2018). Commensal microbiota modulate gene expression in the skin. *Microbiome, 6*, 1–15. https://doi.org/10.1186/s40168-018-0404-9

Publications

Saseevan, S., Nishanthi, N., Rajapakse, S., & Magana-Arachchi, D. N. (2024). Exploring urinary biomarkers for the diagnosis of diabetic and hypertensive chronic kidney disease: A promising pilot study. *Indian Journal of Experimental Biotechnology, 62*(11), 884–894.

Saseevan, S., Rajapakse, S., & Magana-Arachchi, D. N. (2022). RNA extraction from urine sediment: A cost-effective protocol for gene expression analysis in renal pathology. *Ceylon Journal of Science, 51*(5).

Thesis reference

Saseevan S. (2024), Study on urinary biomarkers and urine microbiome in a cohort of diabetic and hypertensive chronic kidney disease patients in Sri Lanka, PhD thesis Postgraduate Institute of Science, University of Peradeniya.

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DEVELOPMENT OF CdS AND CdTe THIN FILMS FOR THIN FILMS SOLAR CELL APPLICATIONS

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Cadmium sulfide (CdS) and cadmium telluride (CdTe) have been identified as popular candidates for large-area electronic devices and solar cells considering the group II and VI semiconductor compounds. It shares 3.5% of the world's PV module demand. CdS is an n-type semiconducting material with a direct bandgap of 2.42 eV. CdS is also considered an excellent partner to be used as the window layer material for CdTe based solar cells due to low resistivity, high transparency, better interconnectivity, and roughness.

CdTe exists in zincblende (cubic) or wurtzite (hexagonal) structure with an ideal direct band gap of 1.45 eV and an absorption coefficient greater than 1×10^5 cm^{-1}, close to the absorption edge, proving ideal for efficient PV energy conversion. According to the theoretical calculations, an energy bandgap between 1.00 – 2.00 eV is more suitable for solar energy conversion with an optimum band gap value of 1.40 eV.

In 1972 for the first time, CdTe solar cells were introduced by Bonnet and Rabenhorst with 3-5% power conversion efficiency with V_{OC} of 500 – 600 mV, I_{SC} of 11 – 14 mA cm^{-2}, and FF usually less than 50%. “BP solar” company started a new chapter with CdTe thin film solar cells using electrodeposition in 1980 and later achieved 11% efficiency in 2000. High-temperature deposition improves CdTe crystallinity and grain size, reducing recombination losses. Post-deposition $CdCl_2$ treatment further enhances stoichiometry, grain boundary passivation, and carrier lifetime.

Additional steps such as chemical etching, annealing, and controlled copper doping improve contact quality and p-type conductivity. Together, these process optimizations have enabled CdTe solar cells to consistently achieve power conversion efficiencies above 15%. Ferekides et. al. demonstrated an efficiency of 15.8% followed by the 16.5% achieved by Wu et. al. in National Renewable Energy Laboratories (NREL). This efficiency remained unchanged for about two decades without any improvements. Following that, a US company began research on CdTe using Close spaced sublimation (CSS) technique. They achieved a 21.5% efficiency device, which was later improved to 22.1% in 2016 with the help of $CdCl_2$ vapor treatment while theoretically having 30% efficiency.

CdS thin films are widely used in various applications such as light-emitting diodes (LED), solar cells, and electronic and optoelectronic devices. Different methods have been used to deposit CdS thin films. CdS, being an n-type window layer material, can be combined with CIGS or CdTe to form a good heterojunction.

Solar photovoltaic technologies are particularly important in promoting wider acceptance of renewable energy. However, the low use of photovoltaics is mostly due to the high initial cost associated with commercial crystalline semiconductor solar technology. On the other hand, thin film solar cells are a promising solution for low-cost solar energy conversion applications. Nonetheless, one key barrier to the commercial viability of thin film solar cells is the need to improve their efficiency. This study includes four separate investigations targeted at increasing the efficiency of CdS/CdTe thin film solar cells. Fig*ure* 1 depicts the basic structure of the solar cell.

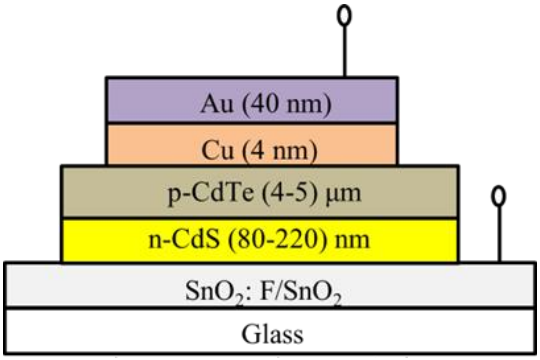

Figure 1. The basic structure of glass/FTO/CdS/CdTe/Cu/Au.

Methodology

In the initial investigation, Cadmium-sulfide (CdS) thin films were successfully deposited through the chemical-bath deposition (CBD) method. This was achieved under stable bath-temperature conditions at 40 °C and 80 °C, as well as under variable bath conditions by altering the temperature from 40–80 °C and 80–40 °C during deposition. GIXRD analysis confirmed the formation of the hexagonal phase of CdS with (002) most prominent orientation for films deposited under both constant and variable temperature conditions. Further it confirms the absence of impurity phases. Notably, the sample deposited at 80 °C exhibited superior crystallinity. SEM investigations indicated an infilling of CdS in sample 80−40 °C when the bath temperature was lowered from an initial high temperature. The resulting lower surface roughness of S80−40 suggested a reduced effective surface area, facilitating lower I-V values. Despite the formation of small clusters, films deposited at 40 °C displayed better electrical and optical properties, primarily due to improved morphological properties.

The impact of $CdCl_2$ treatment on the CdTe layer of CdS/CdTe solar cells produced through the thermal evaporation technique was investigated. GIXRD analysis revealed that $CdCl_2$-treated CdTe films exhibited a polycrystalline structure with a cubic zinc-blende structure. The annealing process at increasing temperatures indicated oxidation of CdTe films. SEM images revealed that CdTe films with improved surface

morphology and larger grains could be obtained when samples were annealed at 400 °C for 20 minutes in air with $CdCl_2$. The CdTe films treated at 400 °C for 20 minutes showed enhanced refractive index, electronic polarizability, optical conductivity, relative density, SELF, VELF, and high absorption coefficient. The optimal FTO/CdS/CdTe/$CdCl_2$/Cu/Au solar cell structure demonstrated J_{SC} of 13.6 mA cm^{-2}, V_{OC} of 668.4 mV, FF of 53.9%, and η of 4.9%, showcasing improved photoactive properties. Fig. 2 shows I-V characteristics of devices prepared with $CdCl_2$ treatment at different annealing temperatures.

Results and Discussion

Thin films of CdS/CdTe/$CdCl_2$/Cu/Au were successfully deposited through thermal evaporation, and their structural, morphological, and electrical characteristics were studied for different etching times. The etching solution used was a standard HNO_3, H_3PO_4, DI water (NP) etchant, where nitric acid served as an oxidizing agent, and phosphoric acid provided an acidic condition. The results indicated variations in the properties of the films with different etching times, highlighting the influence of the etching process. In this study Nitric Phosphoric (NP) etchant was employed to produce a low-resistance Te-rich surface on the CdTe absorber layer. Morphological results suggested that a film etching duration of 35 seconds resulted in a smoother surface compared to other samples. Structural analysis revealed that the formation of a Te-rich surface at 35 seconds and 45 seconds of etching. Thermally evaporated CdTe/CdS etched for 35 seconds exhibited the highest J_{SC} of 18.5 mA cm^{-2}, V_{OC} of 666 mV, FF of 53.6%, and a power conversion efficiency of 6.59%. The optimum etching time for the solar cell was determined to be 35 seconds using the NP etchant. Table 1 shown the summary of the electrical data.

It was observed that superior CdS/CdTe thin film solar cells can be grown using the thermal evaporation technique by introducing an electrodeposited CdTe thin film seed layer before the growth of the CdTe absorber. The introduction of this seed layer significantly increased the grain size of CdTe thin films, leading to improved photoactive performance. The efficiency of the device varied with the thickness of the electrodeposited CdTe seed layer, with the best performance observed with a 50-second electrodeposition, resulting in a V_{OC} of 635 mV, J_{SC} of 15.6 mA cm^{-2}, and FF of 49%.

This study looked at up to four separate investigations, including CdS layer with bath temperature adjustments, $CdCl_2$ heat treatment, NP etching duration modifications, and CdTe seed layer deposition on top of the CdS. Further study could include increasing the number of layers, optimizing the layer count, and investigating annealing in other environments such as N_2 and O_2. Furthermore, $CdCl_2$ studies were conducted in various annealing environments. Properties of the CdS and CdS/CdTe were analyzed and compared.

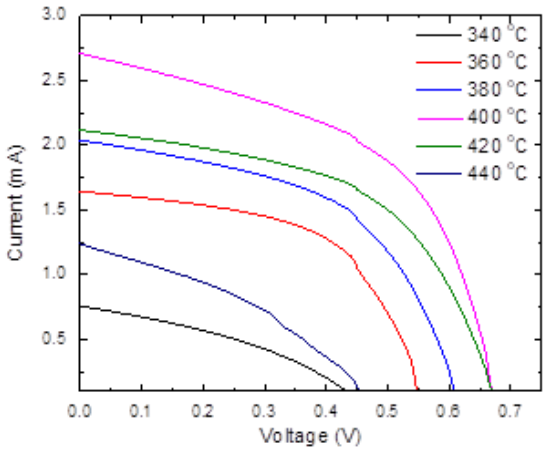

Figure 2. Current-voltage characteristic of different CdCl2 annealing temperatures.

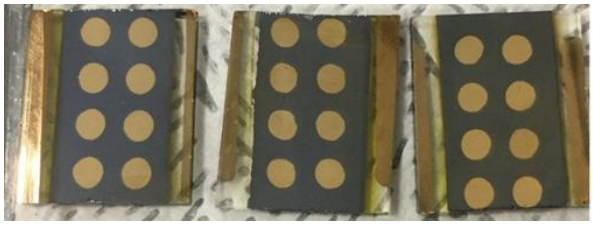

Figure 3. Growth CdS/CdTe/$CdCl_2$/Cu/Au thin films in the AMRel.

Table 1. CdS/CdTe cells highest recorded electrical values for different etching times.

Etching time (s)	J_{SC} (mA cm^{-2})	V_{OC} (mV)	FF (%)	Eff (%)	R_S (Ω/cm)	R_{SH} (Ω/cm)
25	9.95	582	49.4	3.36	57	842
30	12.80	655	53.2	4.08	43	908
35	18.50	666	53.6	6.59	12	1125
40	16.05	658	51.2	5.14	28	983
45	12.40	634	47.5	3.89	45	875

Conclusion

This work demonstrated systematic investigations into the optimization of CdS/CdTe thin-film solar cells through multiple fabrication and post-deposition treatments. CdS thin films deposited via chemical-bath deposition revealed that bath temperature strongly influenced crystallinity, morphology, and optoelectronic behavior, with films deposited at 40 °C showing superior electrical and optical performance despite the presence of surface clusters. $CdCl_2$ activation treatment of thermally evaporated CdTe layers significantly enhanced crystallinity, grain size, and optical constants, leading to improved device efficiency. Optimization of etching duration using NP etchant established 35 seconds as the optimum condition, resulting in smoother surfaces, Te-rich layers, and the highest efficiency of 6.59%. Furthermore, the introduction of an electrodeposited CdTe seed layer prior to absorber growth increased grain size and improved overall device performance.

Collectively, these studies highlight that careful control of deposition parameters, thermal treatments, and surface modifications are critical to enhancing the structural and optoelectronic properties of CdS/CdTe thin films. Future work should explore multilayer optimization, extended annealing environments, and the synergistic effects of combining these treatments to further advance device efficiency.

Acknowledgement

I sincerely thank my research supervisors, late Dr. B.S. Dassanayake and Prof. L.B.D.R.P. Wijesundera, for their invaluable guidance and support throughout this project. I am especially grateful to the late Dr. B.S Dassanayake a remarkable mentor and human being whose unwavering support shaped my academic journey. I also acknowledge the Board of Study in Physics and the PGIS for their guidance. My thanks extend to Mr. P.K.K. Kumarasinghe, Dr. K.G.C. Kumarage, Mr. M.R.M.B. Abeykoon, Mr. K.L.G. Sankalpa, Mr. A.G.A.B. Dissanayake, Mr. N. Mendis, and my colleagues Miss S.S. Withanage and Mr. A.A.I. Lakmal for their continued support. Finally, I am deeply grateful to my parents and family for their love and encouragement throughout this journey.

Selected References

Amarasinghe, M., [et al.]. (2018). Influence of CdTe deposition temperature and window thickness on CdTe grain size and lifetime after $CdCl_2$ recrystallization. *IEEE Journal of Photovoltaics, 8*(2), 600–603.

Dharmadasa, I. M., & Ojo, A. A. (2017). Unravelling complex nature of CdS/CdTe based thin film solar cells. *Journal of Materials Science: Materials in Electronics, 28*(22), 16598–16617.

Fardi, H., & Buny, F. (2013). Characterization and modeling of CdS/CdTe heterojunction thin-film solar cell for high efficiency performance. *International Journal of Photoenergy, 2013,* Article 2013.

Katharina, L. (2003). Solar system abundances and condensation temperatures of the elements. *Astrophysical Journal, 591*(2), 1220.

Kumarage, W. G. C., Wijesundera, R. P., Seneviratne, V. A., Jayalath, C. P., & Dassanayake, B. S. (2017). A study on the enhancement of opto-electronic properties of CdS thin films: Seed-assisted fabrication. *Semiconductor Science and Technology, 32*(4), Article 045001.

Kumarasinghe, P. K. K., Dissanayake, A., Pemasiri, B. M. K., & Dassanayake, B. S. (2017). Thermally evaporated CdTe thin films for solar cell applications: Optimization of physical properties. *Materials Research Bulletin, 96,* 188–195.

Publications

Kumarage, W. G. C., Kumarasinghe, R. K. K. G. R. G., Wijesundera, R. P., Jayalath, C. P., Kaur, N., Comini, E., & Dassanayake, B. S. (2019). *A study on $CdCl_2$ activation of CBD-CdS thin films.* In *Proceedings of the International Conference on Advanced Materials for Clean Energy and Health Applications* (p. 43).

Kumarasinghe, P. K. K., Kumarage, W. G. C., Kumarasinghe, R. K. K. G. R. G., Sankalpa, K. L. G., & Dassanayake, B. S. (2017). *A study on fabrication and characterization of CdTe/CdS thin film solar cells.* In *Proceedings of the Postgraduate Institute of Science Research Congress* (p. 143). Sri Lanka.

Kumarasinghe, R. K. K. G. R. G., Dassanayake, B. S., Kumarage, W. G. C., & Sankalpa, K. L. G. (2018, August 23–28). *Effect of N_2-purging and N_2-annealing on chemical bath deposited CdS thin films.* In *Proceedings of the 4th International Conference of Advances in Functional Materials (AFM)* (p. 55). Nanjing, China.

Kumarasinghe, R. K. K. G. R. G., Kumarage, W. G. C., Wijesundera, L. D. B. R. P., Seneviratne, V. A., Jayalath, C. P., & Dassanayake, B. S. (2019). *Effect of seed layer on opto-electronic properties of CdS thin film.* Uva Wellassa University of Sri Lanka.

Kumarasinghe, R. K. K. G. R. G., Kumarage, W. G. C., Wijesundera, R. P., Jayalath, C. P., Kaur, N., Comini, E., & Dassanayake, B. S. (2019, January 19–22). *A study on $CdCl_2$ activation of CBD-CdS thin films.* AMCHA – University of Jaffna, Sri Lanka.

Kumarasinghe, R. K. K. G. R. G., Kumarage, W. G. C., Wijesundera, R. P., Kaur, N., Comini, E., & Dassanayake, B. S. (2020). *A comparative study on CdS film formation under variable and steady bath-temperature conditions. Semiconductors, 54*(8), 838–843. https://doi.org/10.1134/S1063782620080126

Kumarasinghe, R. K. K. G. R. G., Kumarage, W. G. C., Wijesundera, R. P., Kaur, N., Comini, E., Gunawardhana, N., & Dassanayake, B. S. (2018, August 23–28). *Opto-electric properties of chemical bath deposited CdS films fabricated under variable and steady bath conditions.* In *Proceedings of the 4th International Conference of Advances in Functional Materials (AFM)* (p. 56). Nanjing, China.

Kumarasinghe, R. K. K. G. R. G., Kumarasinghe, P. K. K., Wijesundera, R. P., & Dassanayake, B. S. (2022). *Thermally evaporated CdS/CdTe thin film solar cells: Optimization of $CdCl_2$ evaporation treatment on absorber layer. Current Applied Physics, 33,* 33–40. https://doi.org/10.1016/j.cap.2021.10.011

Lakmal, A. A. I., Kumarasinghe, R. K. K. G. R. G., Maddumage, D. C., Kumarage, W. G. C., Munasinghe, M. A. H. M., Seneviratne, V. A., & Dassanayake, B. S. (2019). *Effect of substrate temperature variation on opto-electronic properties of thermally evaporated CdS thin films.* In *Proceedings of the 4th International Research Symposium on Pure and Applied Sciences, Faculty of Science, University of Kelaniya.* Sri Lanka.

Lakmal, A. A. I., Kumarasinghe, R. K. K. G. R. G., Seneviratne, V. A., & Dassanayake, B. S. (2020). *Effect of film thickness on characteristic properties of thermally evaporated cadmium sulphide thin films.* Faculty of Science, University of Kelaniya, Sri Lanka.

Lakmal, A. A. I., Kumarasinghe, R. K. K. G. R. G., Seneviratne, V. A., Chen, J.-Y., Song, J.-M., & Dassanayake, B. S. (2021). *Thermally evaporated CdS thin films for CdS/CdTe solar cells: Effect of substrate temperature on CdS layer. Materials Science and Engineering: B, 273,* 115406. https://doi.org/10.1016/j.mseb.2021.115406

Lakmal, A. A. I., Kumarasinghe, R. K. K. G. R. G., Seneviratne, V. A., Thanihaichelvan, M., & Dassanayake, B. S. (2022). *Effect of CdS layer thickness on thermally evaporated-CdS/CdTe solar cell efficiency. Journal of Materials Science: Materials in Electronics, 33,* 15627–15637. https://doi.org/10.1007/s10854-022-08467-4

Sankalpa, K. L. G., Kumarasinghe, R. K. K. G. R. G., Kumarage, W. G. C., & Dassanayake, B. S. (2021). *Enhancement of photo-electrical properties of CdS thin films: Effect of N_2 purging and N_2 annealing. Electronic Materials, 5*(1), 30–44. https://doi.org/10.3390/electronicmat5010003

Wijesinghe, W. K. D. A. U., Kumarasinghe, R. K. K. G. R. G., Kumarage, W. G. C., Wijesundera, R. P., Seneviratne, V. A., Jayalath, C. P., & Dassanayake, B. S. (2018, November 9–11). *Growth and characterization of seed assisted Cd(1-x)ZnxS with EDTA treatment.* In *Proceedings of the Postgraduate Institute of Science Research Congress.* Sri Lanka.

Thesis reference

R.K.K.G.R.G. Kumarasinghe, Development Of CdS and CdTe Thin Films for Thin Films Solar Cell Applications. M.Phil in Physics Thesis, Post Graduate Institute of Science, University of Peradeniya, Peradeniya (2024).

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ENHANCING PERFORMANCES IN DYE-SENSITIZED SOLAR CELLS: MIXED-POLYMER GEL ELECTROLYTES WITH LOW AND HIGH MOLAR-WEIGHT POLYMERS AND La_2O_3 BLOCKING LAYER ON PHOTO-ANODES

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The call of current world for green energy sources has triggered extensive research into photovoltaic technologies that are not only cost-effective but also efficient and environmentally friendly as well. Among emerging solar cell technologies, DSSCs have attracted considerable attention due to their unique merits, including simple manufacturing processes that do not require expensive vacuum machines, high performances at cloudy and diffuse light conditions that particularly suit cloudy weather conditions, and the potential for semi-transparent and colorful designs that enable architectural integration into facades and windows. Even though these potential benefits position DSSCs as potential substitutes for conventional silicon photovoltaics, two long-standing technology challenges have immensely limited their commercialization and large-scale implementation. The first main limitation lies with extensive electron recombination losses on the key interface of photo-anode and electrolyte, where photogenerated electrons have the possibility of recombining with oxidized species in the electrolyte before contributing to useful current. The second most problematic challenge arises from relatively poor ionic conductivity typically exhibited by quasi-solid-state electrolytes, which are preferred over liquid electrolytes for improved device stability but typically at the cost of sacrificed charge transport efficiency. These inherent limitations have collectively constrained the power conversion efficiencies and long-term operational stability of DSSC devices to achieve their full potential as practical, commercially viable solar energy solutions.

This research exhaustively addressed these underlying issues with advanced materials engineering methods aimed at both photo-anode architecture and electrolyte composition. The study developed a novel photo-anode architecture with an ultrathin lanthanum oxide (La_2O_3)

blocking layer in a well-optimized multi-layered titanium dioxide (TiO_2) nanostructure that was designed to reduce electron recombination losses drastically while maintaining superior light harvesting efficiency. At the same time, the research pioneered a novel polymer electrolyte system in which high-molecular-weight polyethylene oxide (PEO) was blended in a strategic manner with low-molecular-weight polyethylene glycol (PEG) to realize unprecedented ionic conductivity within a quasi-solid-state matrix without sacrificing good mechanical stability. All these simultaneous material innovations brought significant improvements in both device efficiency and operating stability, and they are major breakthroughs in DSSC technology. The technologies are particularly beneficial to tropical developing nations like Sri Lanka where standard silicon photovoltaics tend to produce sub-optimum output due to common high ambient temperatures and high frequencies of cloud cover that reduce their efficiencies, while simultaneously facing energy access constraints and dependence on fossil fuels. Effective uptake of these optimized DSSCs would substantially reduce reliance on imported fossil fuels while providing a sustainable, locally deployable source of energy specifically designed to work optimally under local environmental conditions as well as with the capabilities of established infrastructure.

The study was guided by an extensive, multi-faceted research method aimed at systematically overcoming the most critical shortcomings in DSSC technology through the well-synchronized development of material and device engineering. The principal research push was towards the development of a next generation photo-anode architecture that would substantially reduce interfacial electron recombination without compromising other critical performance considerations. This involved designing a tightly controlled multi-layered nanostructure of TiO_2 with an ultrathin La_2O_3 blocking layer strategically inserted at the photo-anode/electrolyte interface, where it could effectively block charge recombination while allowing unimpeded electron transport through the TiO_2 network. One supporting research program was underway aimed at reforming the electrolyte system through innovative polymer blending concepts, whereby synergistic blending of high-molecular-weight PEO and low-molecular-weight PEG in optimal composition was designed to overcome the traditional compromise between ionic conductivity and mechanical stability in quasi-solid-state electrolytes. The study included rigorous performance verification procedures using comprehensive current-voltage characterization, comprehensive electrochemical impedance spectroscopy studies, and long-term stability analyses under simulated solar irradiation conditions that represented real-world operating conditions precisely. Moreover, the research developed stable structure-property relationships through extensive material characterization on different length scales, correlating nanoscale material changes with enhanced macroscopic device operation through fundamental understanding of charge generation, transport, and collection mechanisms within the optimized architecture.

Methodology

The experimental strategy integrated state-of-the-art materials synthesis techniques with high-performance characterization equipment to ensure stable and reproducible results with outstanding scientific applicability. The fabrication process of the photo-anode employed a highly controlled layer-by-layer deposition process initiated by an ultra-thin dense TiO_2 film comprising P90 nanoparticles with an average diameter of 13 nm deposited by spin-coating at 2300 rpm on fluorine-doped tin oxide (FTO) glass substrates and followed by controlled thermal sintering at 450 °C to ensure maximal crystallinity and interparticle connectivity. Subsequent layers employed slightly larger P25 TiO_2 nanoparticles with an average diameter of 21 nm, in precisely formulated slurries of accurately calculated amounts of PEG and Triton X-100 surfactants to favor film morphology, porosity, and interfacial adhesion. The last crucial component was deposition of the La_2O_3 blocking layer through a similarly precise spin-coating process and subsequent thermal annealing to create an even nanostructured barrier layer.

Results and Discussion

Detailed structural characterization exhibited exceptional uniformity in layer coverage over large substrate surfaces, and scanning electron microscopy imaging with high resolution clearly demonstrated well-dispersed La_2O_3 nanoparticles with optimal particle size distribution averaging 327.32 nm, which formed a continuous but porous blocking layer with well-controlled thickness of about 1.43 µm. High-resolution X-ray diffraction (XRD) unequivocally confirmed the presence of the necessary anatase TiO_2 and cubic La_2O_3 crystalline phases in the absence of detectable impurities or secondary phases, and quantitative X-ray fluorescence (XRF) analysis indicated the lanthanum content of 38.15%, providing incontrovertible proof of successful blocking layer incorporation. Optical characterization by UV-Vis spectroscopy demonstrated that the broad bandgap of 5.15 eV of the La_2O_3 layer effectively prevented parasitic light absorption in the visible region and created the perfect energy barrier at the photo-anode/electrolyte interface that significantly reduced electron recombination loss without hindering the desired injection of electrons from dye molecules.

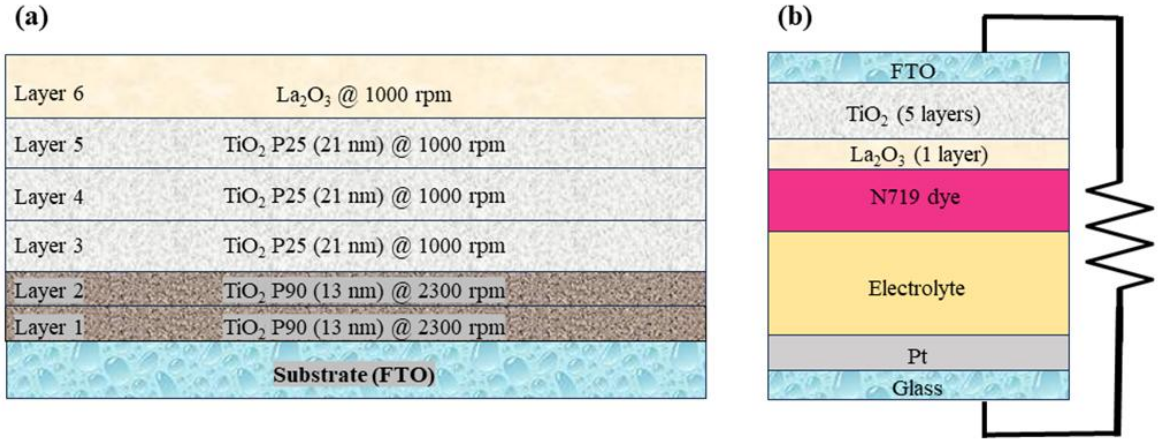

Figure 1. (a) A schematic representation (not to a scale) showing the photo-anode's design with 5 layers of TiO_2 nano-particles and 1 layer of La_2O_3, (b) The configuration of DSSCs

The electrolyte optimization research was an equally rigorous and comprehensive study that tested five different PEO: PEG mix ratios of pure PEO to pure PEG in a sophisticated matrix of ethylene carbonate and propylene carbonate co-solvents, Hex_4NI/LiI dual salt formulations and specifically chosen performance-improving additives such as 4-tert-butylpyridine (4TBP) and 1-hexyl-3-methylimidazolium iodide (HMII). Polarizing microscopy provided tremendous insight into the crystalline structure development of the polymers, where it could be seen well that controlled introduction of PEG progressively disrupted PEO's normal spherulitic structure, thereby significantly reducing crystallinity and producing amorphous regions that facilitated enhanced ion mobility in the electrolyte matrix. Meticulous electrochemical characterization using temperature-dependent impedance spectroscopy revealed unmistakable Vogel-Tammann-Fulcher (VTF) behavior in the ionic transport properties, which would indicate that ion conduction was predominantly via segmental motion of the polymer backbone rather than via approximately simple thermally activated hopping. The optimum composition was found to be 75:25 PEO: PEG. It had the ideal balance of properties like sufficient mechanical strength and size stability provided by the PEO matrix along with excellent ionic conductivity up to 6.86 mS/cm at 30 °C made possible due to the PEG plasticizing effect. This optimum formulation possessed the smallest activation energy for ion transport of 0.149 meV, and it is also giving an intrinsic reasoning of why it is better in terms of performance when utilized in full device

configurations, where indeed it had better interfacial contact with the nanoporous photo-anode as well as counter electrode and simultaneously possessed rapid redox iodide/triiodide shuttle transport.

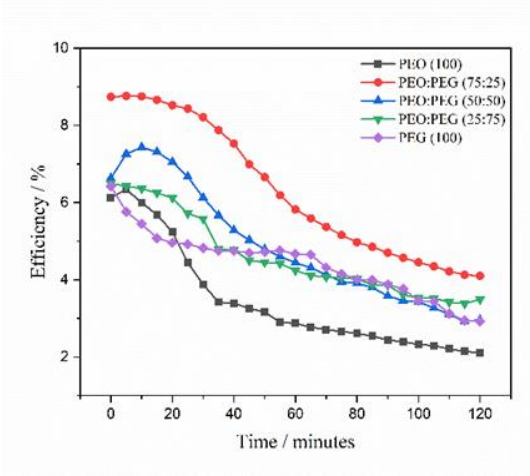

Figure 2. The efficiency vs. time for series of DSSCs with different compositions of electrolytes (Stability variation of DSSCs).

Complete DSSC cells employing the La_2O_3-modified photo-anode and optimized polymer electrolyte exhibited groundbreaking improvements in photovoltaic performance compared to conventional configurations. The modified cells achieved a remarkable power conversion efficiency of 8.50% with normalized AM1.5 irradiation, a whopping 34% higher compared to control cells with normal photo-anodes that achieved merely 6.34% efficiency (Table 1). This dramatic enhancement in performance was accompanied by enhanced current-voltage behavior across all important parameters, including a stellar short-circuit density (J_{SC}) of 17.7 mA/cm^2 and high open-circuit voltage (V_{OC}) of 0.73 V, both significant enhancements over conventional device architectures (Table 1). The 75:25 PEO: PEG optimized electrolyte solution provided an additional performance enhancement, raising champion device efficiency to 8.76% and demonstrating the synergy of the confluence of both material advances within a fully optimized system. Long-term stability tests under continuous illumination for long periods of time indicated that the devices with the modified coumarin dyes maintained more than 90% of their original efficiency after three hours of operation under simulated solar power, indicating superior operating stability that counters one of the built-in limitations of DSSC technology. Electrochemical impedance spectroscopy provided greater mechanistic insight into the superior performance characteristics, showing much lower recombination resistance (R_{rec}) of 10.90 Ω cm^2 compared with 19.05 Ω cm^2 in control devices, which directly confirmed the effectiveness of the La_2O_3 blocking layer in preventing unwanted charge recombination reactions at the photo-anode/electrolyte interface with sufficient charge collection.

The technological innovations developed through this extensive research program have broad implications for many different scientific, environmental, and economic areas. Environmentally, the reduced reliance on phosphorus-based electrolytes and the greatly improved energy conversion efficiency assists in developing solar technology with substantially reduced environmental impact throughout the cradle-to-grave, from production to operation and ultimate decommissioning phases. Replacement of traditional liquid electrolytes with more stable quasi-solid alternatives also addresses long-standing problems of the danger of leakage of the electrolyte and its consequent environmental contamination risks. Economically, large-area solution-based fabrication methods employed, including spin-coating and other printable electronics methods, provide tremendous advantages by lowering production costs dramatically in comparison to traditional silicon photovoltaics that make use of expensive high-temperature vacuum processing but with competitive performance parameters sufficient to make the technology commercially attractive. The fundamental scientific knowledge gained in the nanoscale charge transport mechanisms and interfacial engineering principles has broader applicability outside DSSCs, with recent research directions in other new photovoltaic technologies such as perovskite and organic solar cells being similarly addressed by the same interfacial recombination and optimizing charge transport issues. The experimental material designs and

characterization methods demonstrated may be extrapolated to accelerate advancement in these interrelated fields of investigation, showing the wide-ranging scientific merit of this research.

Future development and research, several promising directions become apparent for moving forward on these considerable breakthroughs. Short-term objectives include up-scaling the technology from laboratory-scale pilot devices to module-level prototypes with performance shown under realistic operating conditions, a step on the pathway to commercial viability. Further optimization might explore other rare-earth oxide blocking layers with electronically optimized characteristics to achieve still higher recombination suppression with maintaining excellent charge transport characteristics. Truly printable DSSC architectures with roll-to-roll compatible processes will be able to provide ultra-low-cost production at industrial scales, and niche applications in building-integrated photovoltaics will be able to harness the sole aesthetic flexibility and diffuse-light performance benefits of DSSCs to establish new markets for architecturally integrated renewable energy generation. Additional basic research could investigate mechanisms for long-term degradation under various environmental stressors to further extend device lifetime, and computational modeling activity could emphasize additional material combinations and architectures for future generations of high-efficiency devices. The successful synergism of materials science, electrochemistry, and device engineering approaches demonstrated here provides an excellent model for future interdisciplinary work to address critical energy needs with innovative materials solutions.

Conclusion

In conclusion, this study has successfully formulated and verified an enhanced high-performance DSSC system through synergistic advancements in the photo-anode, via a La_2O_3 blocking layer, and in the electrolyte, via an optimized PEO: PEG polymer blend. The devices achieved a significant 34% enhancement in power conversion efficiency and radically enhanced operational stability, directly addressing the inherent limitations that have impeded the commercialization of DSSC technology. These developments not only make possible the realization of practical, cost-effective solar energy solutions that are tailored to specific environmental conditions but also provide a sound interdisciplinary basis for further innovation in photovoltaics and materials science.

Table 1. Characteristic parameters of DSSCs for control and developed DSSCs by depositing p- La_2O_3 charge separation layer and for different PEO and PEG -based gel polymer electrolytes.

DSSC Type		J_{SC} / **mA/cm²**	V_{OC} / **V**	*ff*	*PCE* / **%**
Photo-anode Type	TiO_2 (6 layers)	13.4	0.71	0.66	6.34
	TiO_2 (5 layers) + La_2O_3 (1 layer)	17.7	0.73	0.66	8.50
Electrolyte type	PEO (100)	13.4	0.71	0.66	6.34
	PEO: PEG (75: 25)	17.7	0.73	0.68	8.76
	PEO: PEG (50: 50)	16.1	0.72	0.64	7.43
	PEO: PEG (25: 75)	14.6	0.67	0.67	6.49
	PEG (100)	15.6	0.63	0.66	6.42

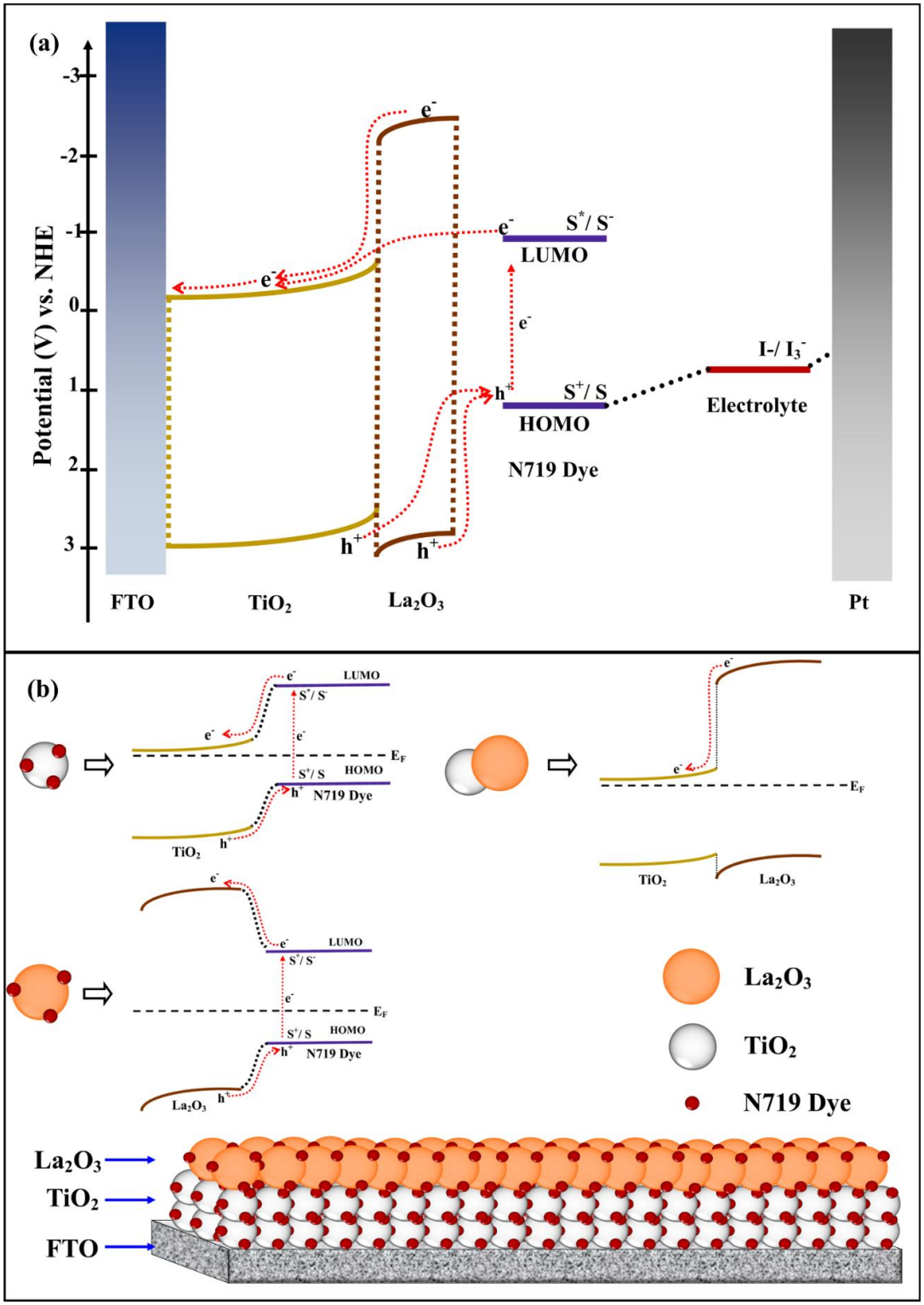

Figure 3. Schematic band diagram (based on real values) and electron-hole transfer; (a) during the operation of the DSSC, and (b) among each particle on photo-anode (La_2O_3, TiO_2, and N719 Dye).

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Selected References

Baxter, J. B. (2012). Commercialization of dye sensitized solar cells: Present status and future research needs to improve efficiency, stability, and manufacturing. *Journal of Vacuum Science & Technology A, 30*(2), 020802. https://doi.org/[insert DOI if available]

Fakharuddin, A., Jose, R., Brown, T. M., Fabregat-Santiago, F., & Bisquert, J. (2014). A perspective on the production of dye-sensitized solar modules. *Energy & Environmental Science, 7*(12), 3952–3981. https://doi.org/[insert DOI if available]

Hagfeldt, A., Boschloo, G., Sun, L., Kloo, L., & Pettersson, H. (2010). Dye-sensitized solar cells. *Chemical Reviews, 110*(11), 6595–6663. https://doi.org/[insert DOI if available]

Hou, T., Xu, W., Pei, X., Jiang, L., Yaghi, O. M., & Persson, K. A. (2022). Ionic conduction mechanism and design of metal–organic framework based quasi-solid-state electrolytes. *Journal of the American Chemical Society, 144*(30), 13446–13450. https://doi.org/[insert DOI if available]

Le Formal, F., Pendlebury, S. R., Cornuz, M., Tilley, S. D., Grätzel, M., & Durrant, J. R. (2014). Back electron–hole recombination in hematite photoanodes for water splitting. *Journal of the American Chemical Society, 136*(6), 2564–2574. https://doi.org/[insert DOI if available]

Lepikko, S., Miettunen, K., Poskela, A., Tiihonen, A., & Lund, P. D. (2018). Testing dye-sensitized solar cells in harsh northern outdoor conditions. *Energy Science & Engineering, 6*(3), 187–200. https://doi.org/[insert DOI if available]

Mozaffari, S., Nateghi, M. R., & Zarandi, M. B. (2017). An overview of the challenges in the commercialization of dye-sensitized solar cells. *Renewable and Sustainable Energy Reviews, 71*, 675–686. https://doi.org/[insert DOI if available]

Rodrigues, D. F., Martins, J., Sauvage, F., Abreu, C. M., Coelho, J. F., Serra, A. C., … Mendes, A. (2024). Suppression of back electron recombination on the photoanode-electrolyte interface with poly(4-vinylbenzoic acid) and poly(4-vinylpyridine) co-adsorbents for stable and efficient dye-sensitized solar cells. *Surfaces and Interfaces, 44*, 103627. https://doi.org/[insert DOI if available]

Zhang, W., Li, S., Zhang, Y., Wang, X., Liu, J., & Zheng, Y. (2022). A quasi-solid-state electrolyte with high ionic conductivity for stable lithium-ion batteries. *Science China Technological Sciences, 65*(10), 2369–2379. https://doi.org/[insert DOI if available]

Publications

Bandara, T. M. W. J., Rajakarunarathne, R. D. M. A. C. B., Wickramasinghe, H. M. N., DeSilva, L. A., Chandrika, R. P., & Yusuf, S. N. F. (2024). Enhancing quasi solid-state dye-sensitized solar cell performance using mixed-polymer gel electrolytes: The influence of low and high molar weight polymers. *Journal of Applied Electrochemistry*, 1–20.

Bandara, T. M. W. J., Rajakarunarathne, R. D. M. A. C. B., Chandrika, R. P., DeSilva, L. A., Tennakone, K., Kumara, G. R. A., & Pitawala, J. C. (n.d.). Enhancing quasi solid-state dye-sensitized solar cell performance by encapsulating N-TiO_2 nanocrystallite-multi-layers by P-La_2O_3 charge separating layer. *SSRN*. https://doi.org/10.2139/ssrn.5234430

Fernando, W. S. S. R., Rajakarunarathne, R. D. M. A. C. B., Bandara, T. M. W. J., & Wijayaratne, K. B. (2024). Quasi-solid-state supercapacitor with coconut shell-derived activated carbon electrodes and H_3PO_4/polyvinyl alcohol gel electrolyte. In *PGIS RESCON Research Congress 2024, Postgraduate Institute of Science, University of Peradeniya* (Vol. 11, p. 221).

Rajakarunarathne, R. D. M. A. C. B., Bandara, T. M. W. J., Dissanayake, S. C., & Maithripala, I. D. (2024). Tailoring crystalline morphology in poly(ethylene oxide)-poly(ethylene glycol) blends for enhanced performance in quasi-solid dye-sensitized solar cells. In *2nd International Conference on Frontiers in Chemical Technology (FCT-2 2024), Institute of Chemistry-Ceylon* (p. 27).

Rajakarunarathne, R. D. M. A. C. B., Bandara, T. M. W. J., & Wickramasinghe, H. M. N. (2023). Enhancing quasi solid-state dye-sensitized solar cell performance using mixed-polymer gel electrolytes: The influence of low and high molar-weight polymers. In *Proceedings of the International Conference on Applied and Pure Sciences, Faculty of Science, University of Kelaniya, Sri Lanka, 2023* (Vol. 3, p. 73).

Thesis reference

Rajakarunarathne, R. D. M. A. C. B. (2024). Enhancing performances in dye-sensitized solar cells: Mixed-polymer gel electrolytes with low and high Molar-weight polymers and La_2O_3 blocking layer on photoanodes. PhD Thesis, Post Graduate Institute of Science, University of Peradeniya, Sri Lanka.

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A STUDY OF BLAST DISEASE ON RICE AND FINGER MILLET CULTIVATIONS IN SRI LANKA, AND THE POPULATION DIVERSITY OF THE CAUSATIVE PATHOGEN *Pyricularia oryzae*

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Blast disease, caused by the ascomycete *Pyricularia oryzae*, is a major threat to global cereal production. The pathogen significantly affects rice (*Oryza sativa* L.) and finger millet *(Eleusine coracana*) production in Sri Lanka. Rice is the staple for over three billion people and the second most grown cereal worldwide. Finger millet is a nutrient-rich cereal and valued for its ability to grow in low-fertile and drought-prone conditions, making it a climate-smart crop. Globally, blast disease causes substantial crop losses: 30% in rice and 28-36% in finger millet (Nalley et al., 2016, Nagaraja *et al*., 2007)

Climate change has increased the frequency of plant diseases, threatening food production and farming livelihoods, and potentially negating future crop yield improvements. Therefore, understanding pathogen strains and their interactions with crops and production environments is vital for sustainable agriculture. *P. oryzae* is a multi-host pathogen infecting over 50 monocot plants, and evidence suggests cross-infection between rice and finger millet blast pathogens. A closely related species, *Pyricularia grisea*, infects crabgrass (genus *Digitaria*) and has a similar colony morphology to *P.* oryzae but affects different hosts. Pathogenicity studies revealed evidence of possible cross-infection between rice and finger millet, and mating experiments confirmed potential cross-compatibility between rice isolates and finger millet isolates of the blast pathogen, resulting in the production of viable progeny.

Variation in pathogenicity and diversity are the main constraints in managing the blast disease.

The rapid emergence of new pathogen strains highlights the importance of expanding fungal collections, offering a valuable opportunity to strengthen disease management strategies through improved understanding and preparedness. Therefore, controlling the emergence and spread of fungal infections needs

robust pathogen surveillance systems. This study investigated blast disease in rice and finger millet in Sri Lanka using a multidisciplinary approach.

Methodology

An island-wide field survey during 2020-2022, spanning major and minor cultivation seasons, assessed disease incidence and severity. Finger millet fields were sampled across 15 agroecological areas in dry and intermediate zones, while rice fields, affected due to a blast outbreak in 2021, were surveyed in six districts across all climatic zones.

Pathogen isolation and characterization involved the collection of infected tissue samples (leaves, necks, panicles, etc.). Koch's postulates were fulfilled for selected isolates of *P. oryzae* to confirm pathogenicity. Morphological characteristics, including colony color and texture, were recorded. Data was analyzed using hierarchical clustering. Pathogenicity tests were conducted on a susceptible rice variety (Bg 94-1) using mycelial suspensions of field-isolated *P. oryzae*.

The genetic diversity and population structure of *P. oryzae* isolates were analyzed. Internal transcribed spacer (ITS) barcode region was sequenced, confirming *P. oryzae* identity and depositing sequences in GenBank. Repetitive element-based PCR (rep-PCR) with *Pot2* primers generated DNA fingerprints for 82 isolates. The *Pot2* diversity was used to analyze population structure and potential gene flow. Bayesian cluster analysis (STRUCTURE) identified the number of distinct pathogen clusters. Further genetic analyses included determining mating type distribution using PCR-based screening for Mat1-1 and Mat1-2 idiomorphs.

Results and Discussion

Rice blast outbreaks were observed in the major season across six districts. In contrast, finger millet blast infections were consistently widespread across all crop stages and districts. Blast pathogens infected all above-ground parts of both crops. In rice, leaf blast had minimal impact, but neck and panicle blast caused severe yield losses with 100% incidence in all affected fields. All popular recommended rice cultivars were susceptible to blast. The neck blast outbreak was sporadic, often sparing adjacent fields. Conversely, finger millet faced high leaf blast incidence (76-100%) during early seedling stages (64%). However, leaf blast incidence decreased significantly as the finger millet crop matured, with 65% of mature crops showing resistance. Neck blast incidence was comparatively low in finger millet (under 50% in over 55% of fields), indicating a degree of field resistance. In summary, rice suffered major economic losses from neck and panicle blast, while losses of finger millet stemmed primarily from leaf blast in early stages, although the disease is found in all crop stages.

Interviews with 49 affected farmers revealed that blast outbreaks in rice were infrequent, with only 24% reporting previous economic losses. Rice farmers observed rapid neck blast development, leading to 100% yield loss within 48-72 hours after symptom onset. Curative fungicides proved largely ineffective. Finger millet farmers reported severe seedling leaf blast, with 25% using fungicides to control the disease spread. But they incurred no economic losses from blast in mature crops and thus did not apply control measures. Most (72%) finger millet farmers relied on traditional varieties and seeds, with limited awareness of recommended cultivars. Both rice and finger millet farmers noted a strong correlation between blast onset and abrupt weather changes, specifically coinciding spikes in humidity and drops in temperature.

A total of 84 *P. oryzae* isolates were collected, *15* from rice and 69 from finger millet. The morphological and molecular data of 84 blast isolates are available in the surveillance tool Sri Lankan *Pyricularia* Diversity Repository (http://www.pgis.pdn.ac.lk/SLPyDR). Koch's postulates confirmed pathogenicity for 15 selected isolates, and their identity was verified through ITS barcoding. Interestingly, other fungal species like *Fusarium* and *Curvularia* were frequently co-isolated from symptomatic finger millet tissues, suggesting potential multiple infections.

Morphological characterization of 84 isolates revealed variations in colony color, pigmentation intensity, and texture, with cottony colonies being most common. The isolates were grouped into four distinct morphological clusters. Most rice isolates formed a unique cluster characterized by distinct pigmentation, although a few clustered with finger millet isolates.

Pathogenicity tests on a susceptible rice cultivar (Bg 94-1) revealed that blast isolates from various infected tissues (leaf, neck, panicle) exclusively caused neck symptoms, indicating high neck tissue susceptibility but there were no tissue-specific infections by the strains tested.

Pot2 Rep-PCR based DNA fingerprints were generated for 82 isolates (15 rice, 67 finger millet). Multilocus genotypes (MLGs) were identified, with a significant amount of clonal fraction, indicating limited genetic variation.

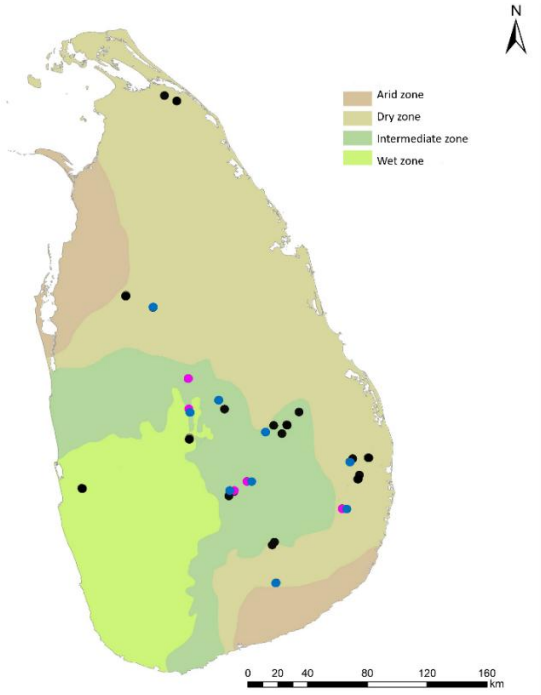

Figure 1. Geographical distribution of the rice and finger millet blast isolates

Genetic analysis of 81 field isolates revealed the presence of both Mat1-1 and Mat1-2 mating types in rice and finger millet populations. Remarkably, a significant amount of the total collection showed amplification of both idiomorphs, indicating mixed mating types. The observation was further validated using single-spore cultures.

Effective disease management of blast disease is crucial to reduce crop losses. In Sri Lanka, high adoption rates of improved rice varieties (97.4%) have effectively reduced leaf blast impact in rice fields. However, a lack of field resistance makes rice cultivars vulnerable to neck and panicle blast during the grain-filling stage. Susceptible landraces, though not causing direct economic losses from leaf blast, were inoculum reservoirs, sustaining a continuous blast threat in fields.

In finger millet, blast infections are consistently widespread across all crop stages, maintaining high inoculum pressure. Although recommended finger millet varieties are moderately resistant to leaf blast, varietals adoption rate is low (<28%). Thus, two significant susceptibility windows were identified in finger millet leaf blast in seedlings and neck/finger blast in mature crops. Therefore, controlling blast needs introducing cultivars with durable genetic resistance and practices to reduce inoculum, progressively removing susceptible plant material.

Conclusion

Genetic resistance to neck and panicle blast is largely lacking in local elite rice germplasm. Therefore, breeding programs must prioritize broadening the genetic base for these traits, with an emphasis on incorporating race-nonspecific resistance to achieve durable protection. In the case of finger millet, which is cultivated across diverse agro-ecological zones and by farmers with limited access to agrochemicals, efforts to enhance field resistance should focus on leveraging multiple mechanisms of blast resistance, including adult plant resistance.

These findings highlight the critical need for integrated disease management and strengthened pathogen surveillance systems to improve blast outbreak preparedness and resilience in Sri Lanka’s changing agricultural landscapes.

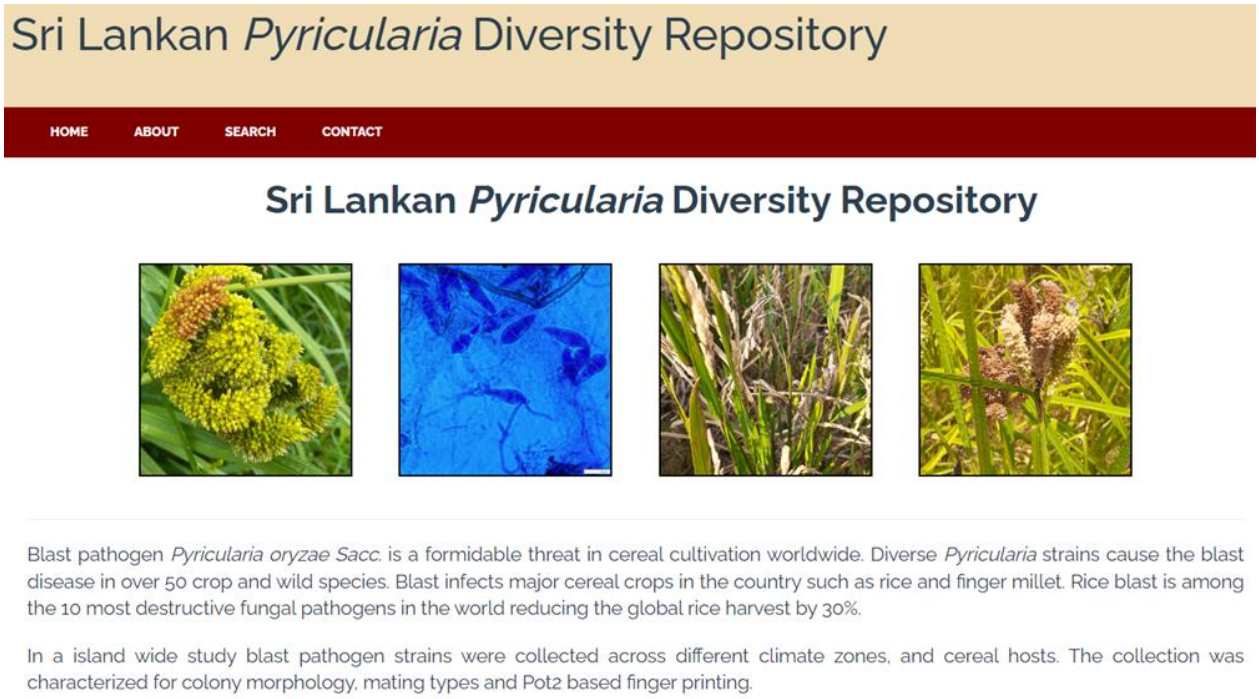

Figure 2. Home page of Sri Lankan *Pyricularia* Diversity Repository

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Selected References

Babu, T. K., Thakur, R. P., Upadhyaya, H. D., Reddy, P. N., Sharma, R., Girish, A. G., & Sarma, N. D. R. K. (2013). *Resistance to blast (Magnaporthe grisea) in a mini-core collection of finger millet germplasm. European Journal of Plant Pathology,* 135(2), 299–311. https://doi.org/10.1007/s10658-012-0085-4

International Rice Research Institute (IRRI). (2002). *Standard evaluation system for rice (SES).* International Rice Research Institute.

Khadka, R. B., Shrestha, S. M., Manandhar, H. K., & Gopal, B. K. C. (2012). *Study on differential response of Pyricularia grisea isolates from rice, finger millet, and Panicum sp. with local and alien media, and their host range. Nepal Journal of Science and Technology,* 13(1), 7–14.

Nagaraja, A., Jagadish, P. S., Ashok, E. G., & Gowda, K. T. K. (2007). *Avoidance of finger millet blast by ideal sowing time and assessment of varietal performance under rainfed production situations in Karnataka. Journal of Mycopathological Research,* 45(2), 237–240.

Nalley, L., Tsiboe, F., Durand-Morat, A., Shew, A., & Thoma, G. (2016). *Economic and environmental impact of rice blast pathogen (Magnaporthe oryzae) alleviation in the United States. PloS One,* 11(12), e0167295.

Peakall, R., & Smouse, P. E. (2006). *GENALEX 6: Genetic analysis in Excel. Population genetic software for teaching and research. Molecular Ecology Notes,* 6, 288–295.

Peakall, R., & Smouse, P. E. (2012). *GenAlEx 6.5: Genetic analysis in Excel. Population genetic software for teaching and research – an update. Bioinformatics,* 28, 2537–2539.

Porras-Hurtado, L., Ruiz, Y., Santos, C., Phillips, C., Carracedo, Á., & Lareu, M. V. (2013). *An overview of STRUCTURE: Applications,*

parameter settings, and supporting software. Frontiers in Genetics, 4, 98.

Team RC. (2013). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing.

Publications

Dasanayaka, B. I., Dissanayaka, D. M. H. R., Abeysiriwardena, D., Sumith de Z, & Ariyarathna, H. A. C. K. (2023). *The SALTOL loci from FL 478 was incorporated into elite variety BG 352 by marker-assisted selection in rice.* In *Proceedings of the Postgraduate Institute of Science, Research Congress, Sri Lanka, 2023.*

Dissanayaka, D. M. H. R., Daundasekera, W. A. M., & Ariyarathna, H. A. C. K. (2022). *A case report on the blast disease outbreak in "Maha" season 2021 in rice.* In *Proceedings of the Second National Symposium of Plant Health, Sri Lanka Association for Mycology and Plant Pathology* (p. 21).

Dissanayaka, D. M. H. R., Daundasekera, W. A. M., & Ariyarathna, H. A. C. K. (2025). *PyDRSL—Sri Lankan Pyricularia Diversity Repository: A web-based tool for fungal pathogen surveillance.* In *Proceedings of the Second National Symposium of Plant Health, Sri Lanka Association for Mycology and Plant Pathology* (p. 23). http://www.pgis.pdn.ac.lk/SLPyDR

Dissanayaka, D. M. H. R., Daundesekera, W. A. M., & Ariyarathna, H. A. C. K. (2020). *Identification of fungal pathogens associated with finger millet (Eleusine coracana) in Sri Lanka.* In *Proceedings of the Postgraduate Institute of Science, Research Congress, Sri Lanka, 2020.*

Dissanayaka, D. M. H. R., Daundesekera, W. A. M., & Ariyarathna, H. A. C. K. (2021). *Pyricularia oryzae isolates regardless of their origin from different symptomatic organs caused neck blast in inoculated rice plants.* In *Proceedings of the Postgraduate Institute of Science, Research Congress, Sri Lanka, 2021.*

Dissanayaka, D. M. H. R., Pabasara, M. D., Gajanayake, G. K. S. N., Daundasekera, W. A. M., & Ariyarathna, H. A. C. K. (2024). *A case report on blast disease in rice and finger millet. Ceylon Journal of Science,* 53(2), 193–196. https://doi.org/10.4038/cjs.v53i2.8399

Dissanayaka, D. M. H. R., Wakkumbura, J. R., Daundasekera, W. A. M., Abeysundara, S. P., Fernando, W. M. K., Wijewardena, D. C. M. S. I., & Ariyarathna, H. A. C. K. (2025). *Rich standing variability and seasonal dynamics drive shifts in cereal blast pathosystems in Sri Lanka. Manuscript accepted for presentation at the American Society of Plant Biologists (ASPB) Southern Section.*

Ruwanthika, A. M. C., Jayawardane, N. U., Bulathsinhalage, V. N. D., Dissanayaka, D. M. H. R., & Ariyarathna, H. A. C. K. (2023). *Genotyping and phenotyping of selected rice germplasm for blast disease resistance under local conditions.* In *Proceedings of the Postgraduate Institute of Science, Research Congress, Sri Lanka, 2023.*

Thesis reference

Dissanayaka D.M.H.R. (2025). A Study of Blast Disease on Rice and Finger Millet Cultivations in Sri Lanka, and The Population Diversity of the Causative Pathogen *Pyricularia Oryzae.* M.phil. Thesis, Postgraduate Institute of Science, University of Peradeniya.

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DEVELOPMENT AND EVALUATION OF A TOPICAL HERBAL FORMULATION OF *Piper betle* FOR THE TREATMENT OF SUPERFICIAL CANDIDIASIS

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The prevalence of fungal infections has been increasing over the last decades, being more dominant in developed countries. Superficial candidiasis caused by *Candida albicans, C. tropicalis, C. parapsilosis, C. glabrata* etc., was responsible for 50-90% of all cases of human candidiasis. It is often associated with immunosuppression, poor hygiene, or prolonged antibiotic use. The major causative agent has a capacity to induce oral cancer by directly producing different carcinogenic compounds, when immunity is suppressed. Azole and polyene antifungals are effective but increasingly limited by resistance, adverse effects, and cost (Pfaller & Diekema, 2007). Formulations such as creams, ointments, and tablets are used in the treatment of superficial fungal infections, especially for Candida infections. Considering the concentration of drug and the degree of solubility, topical formulations

are said to be beneficial for treating localized superficial fungal infections.

Piper betle contains phenols, flavonoids, and essential oils possessing antimicrobial activity (Nayaka et al., 2018; Nanayakkara et al., 2014). Previous studies have shown its efficacy against various bacterial and fungal pathogens; however, its potential in standardized topical antifungal formulations targeting *C. albicans* remains unexplored. The aim of this research is to formulate a pharmaceutically acceptable herbal formula which can effectively treat superficial candidiasis.

Methodology

Leaves of five commonly available *P. beetle* cultivars (Maneru, Ratadalu, Narammali, Sudu-Nagawalli, and Kaha-Nagawalli) were collected at the intercropping betel research station at Narammala, Sri Lanka. Organoleptic, morphological, and microscopic evaluation were determined per standard methods (Ali et al., 2010).

Piper betle crude extracts were prepared with fresh leaves by using solvents such as ethanol, ethyl acetate, chloroform, hot water chloroform, and isopropyl alcohol separately. Standard phytochemical tests and Gas Chromatography Mass Spectrometry were used to identify alkaloids, phenols, flavonoids and tannins (Biswas et al., 2022).

The antifungal activity of the plant extracts was evaluated using the agar well diffusion method against standard strains of *Candida albicaens, Candida glabrata, Candida krusei, Candida parapsilosis* and *Candida tropicalis* (ATCC strain). Sterile Sabouraud Dextrose Agar (SDA) plates were inoculated with fungal suspensions (adjusted to 0.5 McFarland standard, $\approx 1\times10^6$ CFU/mL). Wells were bored aseptically, and 200 µL of each extract was introduced into the wells. Plates were incubated at 37 °C for 24 hours, and the diameter of the inhibition zones was measured in millimeters. The minimum inhibitory concentration (MIC) was determined using the broth microdilution method. The MIC was defined as the lowest concentration showing no visible growth.

Based on antifungal screening results, the most potent plant crude extract was incorporated into a topical cream. It was formulated in an oil-in-water (O/W) emulsion base, consisting of an oil phase (stearic acid, cetyl alcohol, and mineral oil) and an aqueous phase. The mixture was homogenized under controlled temperature conditions to obtain a stable emulsion. The formulated cream was subjected to preliminary physicochemical stability testing, including pH determination (digital pH meter), viscosity measurement (Brookfield viscometer), and spreadability (glass slide method).

An in vivo antifungal efficacy was tested using healthy adult albino mice (n=24). To suppress the immune system of the mice, two doses of methyl prednisolone were injected subcutaneously in the lower abdominal peritoneum over three days. Immediately after the second injection, yeast suspension was administered into the oral and vaginal cavities of the mice. After confirmation of infection, mice were randomly assigned into five treatment groups: GROUP I - An infected group that received herbal cream, GROUP II - An infected group that received placebo base cream, GROUP III - An infected group that received commercial antifungal cream, GROUP IV- A control group infected with *C. albicans* without treatment and GROUP V - A non-infected control group without treatment. Treatments were applied twice daily for 14 consecutive days. Clinical assessment included recovery of Candidiasis. At the end of the study, animals were euthanized humanely, and tongues and vaginal samples were collected for histopathological evaluation of tissue regeneration, inflammation, and fungal clearance. Additionally, systemic toxicity was assessed through histological examination of vital organs (liver, kidney, and heart) to ensure the safety of the formulated herbal cream.

A structured survey was conducted across 30 community pharmacies to document the range of antifungal products currently available in the local market. Data collection focused on identifying the formulations (creams, ointments,

powders, oral tablets), the active pharmaceutical ingredients (APIs) commonly employed (such as clotrimazole, miconazole, ketoconazole, terbinafine, fluconazole), and their respective concentrations. In addition, the retail pricing of these products was systematically recorded to evaluate affordability and accessibility for patients. Information gathered from the survey provided valuable insight into the prevalence of synthetic antifungals, the degree of market competition, and the cost variations among different brands and formulations. This baseline data served as a benchmark for comparing the potential positioning and cost-effectiveness of the newly developed herbal antifungal cream.

Results and Discussion

Comparative morphological and anatomical traits in Sri Lankan common *Piper betle* cultivars; Maneru, Ratadalu, Narammali, Sudu-Nagawalli, and Kaha-Nagawalli exhibited marginal variation in leaf morphology, including shape, base, odor, apex, and length-to-width ratio. Stomatal arrangement, vein islet number, vein termination, and stomatal index remained consistent across all cultivars. Distinctive oil body distribution in *P. betle* type; Kaha-Nagawalli displayed oil bodies exclusively on the abaxial leaf surface, whereas other cultivars possessed oil bodies on both adaxial and abaxial surfaces, suggesting cultivar-specific adaptations.

Biochemical testing of *P. betle* crude extract from the solvents of ethyl acetate, methanol, chloroform, water/ chloroform and iso-propyl alcohol revealed the presence of alkaloids, terpenoids, phenols, flavonoids, steroids and tannins. Cardiac glycosides were not identified in these solvent extracts. Further, screening of the chemical profile of crude extract using the above solvents using GC-MS analysis. Among the chemical compounds, the major component is Eugenol, which is responsible for the flavor and aroma of the leaves. Different solvent crude extracts of *P. betle* possess the highest content of Eugenol and could be used as a promising variety in the pharmaceutical industry.

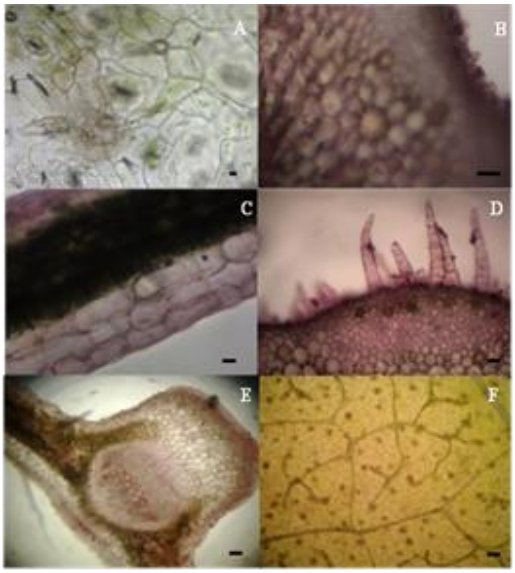

Figure 1. Prominent microscopic characteristics of *P. betle* cultivars. Transverse section of *P. betle* leaf A) Oil bodies at the lower leaf epidermis of Kaha Nagawalli B) Oil bodies at the leaf petiole in Ratadalu C) Oil bodies in below the spongy mesophylls cells in young *P. betel* leaf L.S. D) Epidermal outer growth"Trichoms" –uniseriate, multicellular, unbranched in the petiole of Sudu Nagawalli stained with safranin. E) Transvers section of *P. betle* leaf petiole F) Vein islet and vein terminations representing overnight dipping in 10% Potassium Hydroxide (KOH) solution at room temperature. Scale bar represents 1µm

The agar well diffusion bioassay revealed that crude extracts obtained using different solvents exhibited inhibitory effects against *Candida* species, with all solvent types showing measurable activity relative to the negative control and comparable effectiveness to the positive control. Ethyl acetate *P. betle* crude extract exhibited the highest inhibition diameter for tested five *Candida* sp., while the crude extract of iso-propyl alcohol also showed significant anti-candidal activity. No significant difference could be observed for the anti-candidal activity of different solvent betel crude extracts. However, all the tested crude extracts of different solvents at a MIC of 6.4 mg/ml inhibited all the tested *Candida* species. In contrast, less active extracts required higher concentrations to achieve similar inhibitory effects. These results highlighted the selected extract as a promising

antifungal candidate for further formulation studies.

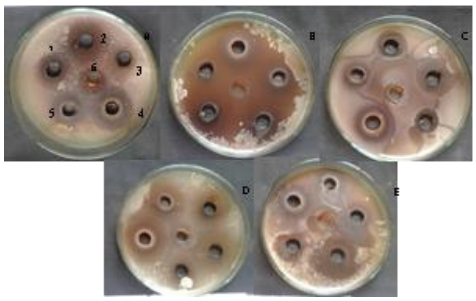

Figure 2. Zone of inhibition given by young leaves of Ratadalu cultivar crude extracts from five different solvents; 1) Ethanol, 2) Chloroform, 3) Ethyl acetate, 4) Iso-propyl alcohol, 5) Methanol, 6) DMSO Negative control against *Candida albicans* after incubation at 37 ºC overnight.

The most active extract was successfully incorporated into a 2% oil-in-water cream base, producing a smooth, homogenous, and cosmetically acceptable formulation. Stability testing conducted over a 90day period revealed no signs of phase separation, color change, or rancidity under both ambient and accelerated storage conditions. The pH of the cream remained within the skin-compatible range (5.5–6.3) throughout the study period. Viscosity measurements indicated minimal fluctuations, confirming consistent texture and spreadability. Spreadability tests also showed uniform application properties, comparable to the commercial antifungal reference cream. Collectively, the stability profile confirmed that the herbal cream formulation was physically and chemically stable over the 3-month evaluation period.

Mice treated with the herbal cream showed a significant recovery compared to both the placebo and untreated control groups. By day 14, the herbal cream group and commercial antifungal cream (positive control) demonstrated 100% recovery from the infection, which was comparable to each other. In contrast, the placebo group exhibited only mild improvement, with lesions persisting throughout the experimental period. Recovery progression was more rapid in the herbal cream group, with visible reduction in erythema, scaling, and inflammation observed one week after treatments. Histopathological examination of the infected tongue and vaginal samples revealed marked improvements in the herbal cream and commercial antifungal groups. Tissue sections from these groups showed re-epithelialization, reduced inflammatory cell infiltration, and absence of fungal hyphae in the epidermis, confirming effective fungal clearance. Conversely, placebo-treated mice displayed persistent fungal colonization and inflammatory changes. Evaluation of systemic toxicity indicated no adverse histological changes in the liver, kidney, or heart of animals treated with the herbal cream, confirming its safety for topical use. Overall, the herbal formulation demonstrated both potent antifungal efficacy and favorable safety characteristics, supporting its potential as an alternative topical treatment for cutaneous candidiasis.

Survey data from 30 pharmacies highlighted that the local antifungal market is dominated by synthetic formulations, with limited availability of plant-based or natural alternatives. The majority of products contained active pharmaceutical ingredients such as clotrimazole, terbinafine, or miconazole. The absence of locally produced herbal antifungal creams presents a commercial gap that could be strategically filled by leveraging indigenous medicinal plants like *P. betle.*

The superior antifungal activity demonstrated by the hot water chloroform crude extract of *P. betle* cultivar can be attributed to its relatively high concentration of phenolic compounds and flavonoids, secondary metabolites well recognized for their broad-spectrum antimicrobial properties. Phenolic compounds are capable of binding to fungal cell wall proteins and disrupting plasma membrane integrity, thereby increasing permeability and ultimately leading to leakage of cellular contents and fungal cell death (Shin & Lim, 2020). This mechanism of action supports the strong inhibition observed against *Candida albicans* in both in vitro and in vivo assays.

Notably, the healing rate observed with the formulated herbal cream was comparable to that of commercially available azole-based creams, which are widely regarded as standard therapy for superficial candidiasis. This finding underscores the clinical potential of the herbal cream as an effective alternative treatment. The absence of systemic toxicity, as evidenced by normal histopathological profiles of the liver, kidney, and heart, further strengthens the safety profile of the preparation, supporting its suitability for long-term topical use.

The pharmacy survey also revealed a limited availability of locally produced, plant-based antifungal creams, with the current market being dominated by synthetic formulations such as clotrimazole, miconazole, and terbinafine. This observation indicates a clear commercial gap and an opportunity for the introduction of affordable, herbal-based antifungal preparations derived from indigenous resources. Such a product could provide a cost-effective alternative for patients while also promoting the valorization of local medicinal plants.

These findings are consistent with global trends that increasingly advocate the development of herbal and natural alternatives for managing fungal infections. With rising concerns over antifungal resistance, side effects, and the cost of synthetic drugs, there is a growing preference toward phytomedicine. Developing affordable herbal creams would not only address unmet patient needs but also support the local pharmaceutical industry by reducing dependence on imported formulations and encouraging value addition to medicinal plants cultivated within the country. Countries with a rich heritage of medicinal plant biodiversity, such as Sri Lanka, are particularly well positioned to contribute to this movement by developing safe, effective, and sustainable plant-based therapies.

Conclusion

The present study demonstrated that the hot water chloroform crude extract of *P. betle* possesses potent antifungal activity against *Candida albicans,* which can be attributed to its high content of bioactive phenolic compounds. Incorporation of this extract into a 2% herbal cream formulation resulted in a stable, safe, and effective preparation that achieved comparable healing rates to commercial azole-based antifungal creams, without inducing systemic toxicity in animal models. These findings confirm the potential of locally sourced herbal formulations as viable alternatives to synthetic antifungal drugs, particularly for the management of superficial candidiasis. The results also highlight a significant commercial opportunity for the development of plant-based antifungal products in Sri Lanka. By utilizing indigenous medicinal plants, such innovations could reduce dependency on imports, lower treatment costs, and promote value addition to local biodiversity.

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Selected References

Ali, S. S., Kasoju, N., Luthra, A., Singh, A., Sharanabasava, H., Sahu, A., & Bora, U. (2008). Indian medicinal herbs as sources of antioxidants. *Food Research International, 41*(1), 1–15. https://doi.org/10.1016/j.foodres.2007.10.001

Biswas, P., Anand, U., Saha, S. C., Kant, N., Mishra, T., Masih, H., Bar, A., Pandey, D. K., Jha, N. K., & Majumder, M. (2022). Betelvine (*Piper betle* L.): A comprehensive insight into its ethnopharmacology, phytochemistry, and pharmacological, biomedical and therapeutic attributes. *Journal of Cellular and Molecular Medicine, 26*(11), 3083–3119. https://doi.org/10.1111/jcmm.17349

Nanayakkara, B. S., Abayasekara, C. L., Panagoda, G. J., Kanatiwela, H. M., & Senanayake, M. R. (2014). Anti-candidal activity of *Piper betle* (L.), *Vitex negundo* (L.) and *Jasminium grandiflorum* (L.). *African Journal of*

Microbiology Research, 8(23), 2307–2314. https://doi.org/10.5897/AJMR2014.6713

Nayaka, N. M. D. M. W., Sasadara, M. M. V., Sanjaya, D. A., Yuda, P. E. S. K., Dewi, N. L. K. A. A., Cahyaningsih, E., & Hartati, R. (2021). *Piper betle* (L.): Recent review of antibacterial and antifungal properties, safety profiles, and commercial applications. *Molecules, 26*(8), 2321. https://doi.org/10.3390/molecules26082321

Pfaller, M. A., & Diekema, D. J. (2007). Epidemiology of invasive candidiasis: A persistent public health problem. *Clinical Microbiology Reviews, 20*(1), 133–163. https://doi.org/10.1128/CMR.00029-06

Shin, S., & Lim, S. (2020). Antifungal properties of phenolic compounds. *Applied Microbiology and Biotechnology, 104*, 1063–1074. https://doi.org/10.1007/s00253-019-10216-9.

Publications and Patents

Jathika Mehewara. (2023, June 27). *TV programme of TV1 by the Vice Chancellor.*

Lakmali, W. G. M., Athukorala, S. N. P., Abayasekara, C. L., Panagoda, G. J., & Jayathilaka, J. A. M. S. (2025). *Pharmacognostic evaluation and in-vitro anti-candidal activity of young leaves of common Piper betle types in Sri Lanka. Manuscript under review, Ceylon Journal of Science.*

Lakmali, W. G. M., Athukorala, S. N. P., Panagoda, G. J., Abayasekara, C. L., Jayathilaka, J. A. M. S., & Nanayakkara, B. S. (2023). *Formulation of a herbal product against oral candidial infection. National patent, Sri Lanka, filed June 18 and submitted August 21, 2023, patent pending. Patent No. LK/P/1/22794.*

Lakmali, W. G. M., Athukorala, S. N. P., Panagoda, G. J., Abayasekara, C. L., Jayathilaka, J. A. M. S., Rajapaksha, P. S., & Jayasinghe, R. D. (2019). *Preliminary pharmacognostic evaluation and in-vitro anti-candidal activity of young leaves of common Piper betle types in Sri Lanka.* In *Proceedings of Postgraduate Institute of Science Research Congress (PGIS RESCON 2019) (11th October 2019).*

National Industry Exhibition 2023. (2023, June 22–25). *Innovation Arena held at BMICH.*

Thesis reference

Madusha Lakmali, W.G., Development and evaluation of a topical herbal formulation of *piper betle* for the treatment of superficial candidiasis, Ph.D. Thesis, Postgraduate Institute of Science, University of Peradeniya.

SCREENING SELECTED INVASIVE PLANT EXTRACTS/ COMPOUNDS FOR ANTIFUNGAL ACTIVITY AGAINST PATHOGENS OF ORNAMENTAL FOLIAGE PLANTS

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Floriculture, a key branch of horticulture, plays an important role in Sri Lanka's economy by generating significant foreign income. Beyond its economic value, floricultural products are widely used in local cultural practices, including weddings, funerals, and interior decorations. The industry relies on the production of high-quality ornamental foliage plants such as *Dracaena, Cordyline, Aglaonema, Calathea, Ophiopogon, Codiaeum, Polyscias*, and *Dieffenbachia*. However, this sector faces serious challenges from fungal diseases caused by pathogens including *Colletotrichum* sp., *Fusarium* sp., *Alternaria* sp., *Aspergillus* sp., *Pestalotia* sp., *Phomopsis* sp., and *Phytophthora* sp., which threaten both yield and quality. Although synthetic fungicides are widely used to manage these diseases, their continued application has raised concerns, including the development of resistance in pathogens, negative environmental impacts, and health risks to humans and animals. As a result, there is an increasing demand for sustainable and eco-friendly alternatives.

Sri Lanka is impacted by the spread of invasive alien plant (IAP) species. IAP species are non-native to an ecosystem and cause considerable harm to the economy, environment and, in some cases, cause adverse effects on human health (Ranwala, 2014). *Mikania micrantha, Tithonia diversifolia, Lantana camara, Clusia rosea, Chromolaena odorata* and *Clidemia hirta* are such problematic IAP species with global and national concerns. Interestingly, many IAPs are known to contain bioactive compounds with

antifungal properties, presenting a unique opportunity to convert these problematic species into useful natural resources.

This study aimed to explore the antifungal potential of selected invasive plant extracts and compounds as environmentally friendly, cost-effective alternatives to synthetic fungicides against selected phytopathogens in ornamental foliage plants.

Methodology

Diseased leaf samples of selected ornamental foliage plant species (*Dracaena, Calathea, Cordyline, Dieffenbachia* and *Polyscias*) were collected and their fungal pathogens were isolated to Potato Dextrose Agar (PDA) medium. The pathogens were identified based on spore morphology and colony characteristics. Pathogenicity tests were performed following Koch's postulates, and pure cultures were subsequently identified to the species level by Genetech, Colombo.

Leaves and roots of the invasive plants; *Mikania micrantha, Clidemia hirta, Tithonia diversifolia, Lantana camara, Clusia rosea*, and *Chromolaena odorata* were collected from the Central Province and subsequently authenticated. Air-dried and powdered plant materials were sequentially extracted with hexane, dichloromethane (DCM), and methanol using an ultrasonicator. The antifungal activity of thirty-six plant extracts was screened using *Cladosporium* bioautography and the disc diffusion bioassay against the isolated phytopathogens.

A bioactive compound was isolated from the most promising plant extract, DCM leaf extract of *M. micrantha*, using bioassay-guided fractionation, employing vacuum liquid chromatography (VLC), flash column chromatography (FCC), and preparative thin-layer chromatography (TLC). A single active compound was successfully isolated, and its antifungal efficacy was evaluated using the thiazolyl blue tetrazolium bromide (MTT)-based minimum inhibitory concentration (MIC) assay. The structure of the isolated antifungal compound was elucidated using various spectroscopic techniques, including UV, IR, HPLC-MS, ^{1}H NMR, and ^{13}C NMR.

Results and Discussion

According to the results, the fungal pathogens *Colletotrichum gloeosporioides, Curvularia eragrostidis, Pestalotiopsis mangiferae, Phomopsis heveicola* and *Fusarium* sp. were the disease-causing agents identified in the selected ornamental foliage plants of *Dracena reflexa* (Jamaica), *Polyscias scutellaria*, *Dracaena fragrans, Dracaena godseffiana*, and *Dracaena sanderiana*, respectively.

The antifungal activity of plant extracts screened by *Cladosporium* bioautography and disc diffusion bioassay showed varying levels of antifungal activities depending on the plant and fungal species. The *Cladosporium* bioassay revealed that the most potent antifungal extract, the DCM leaf extract of *M. micrantha*, contained at least three antifungal compounds of varying polarities. The MIC values in the MTT bioassay of *M. micrantha* DCM leaf extract against *Fusarium* sp., *C. gloeosporioides* and *C. cladosporioides* were 0.25-0.5, 0.5-1 and 0.25-0.5 mg mL^{-1}, respectively. The MIC values for both *T. diversifolia* DCM root extract and *C. odorata* DCM leaf extract against Fusarium sp., *C. gloeosporioides* and *C. cladosporioides* were 0.25-0.5, 0.5-1 and 0.25-0.5 mg mL^{-1}, respectively.

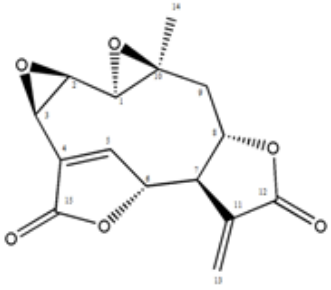

Figure 1. Mikanolide; Isolated antifungal compound from *M. micrantha* leaves

An antifungal compound (Figure 1) was isolated from the dichloromethane leaf extract of *M. micrantha* using a combination of chromatographic techniques, VLC, FCC, and preparative TLC. It was identified as mikanolide

(1, 10:2, 3-diepoxy-6, 8-dihydroxygermacr-4-ene-11-vinyl-12, 14-di-gamma-lactone) by analysis of its spectral data (UV, IR, HPLC-Mass, ^{1}H NMR and ^{13}C NMR) and comparison of the data with those reported in the literature for the same compound (Li *et al*., 2013). The MIC values of mikanolide (and mancoceb) against *Fusarium* sp., *C. gloeosporioides* and *C. cladosporioides* were 0.125-0.25 (0.125-0.25), 0.25-0.5 (0.125-0.25) and 0.125-0.25 (0.125-0.25) mg mL^{-1}, respectively.

Conclusion

The findings from the present study revealed that certain invasive plants possess the potential to be developed as eco-friendly and cost-effective botanical fungicides. The antifungal activity of mikanolide ($C_{15}H_{14}O_6$), against the tested fungal pathogens isolated from diseased leaves of selected ornamental foliate plants is comparable with that of the commercial fungicide Mancozeb. Therefore, *M. micrantha* leaf extracts is a potential source for developing plant-based fungicides to be used in the floriculture industry as eco-friendly plant-based fungicides to effectively control selected fungal diseases on ornamental foliage plants.

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Selected References

Damunupola, J. W., Nanayakkara, B. S., & Herath, H. E. (2014). Common fungal diseases of selected ornamental foliage plants. *Proceedings of the Peradeniya University International Research Sessions, Sri Lanka, 18*, 580.

Li, Y., Li, J., Li, Y., Wang, X. X., & Cao, A. C. (2013). Antimicrobial constituents of the leaves of *Mikania micrantha* HBK. *PLOS ONE, 8*(10), e006725. https://doi.org/10.1371/journal.pone.006725

Ranwala, S. M. W. (2014). Stakeholder participation in management and control of invasive alien flora in Sri Lanka. *Proceedings of the National Symposium on Invasive Alien Species, Sri Lanka, 1*, 9.

Wijesundara, S. (2010). Invasive alien plants in Sri Lanka. In B. Marambe, P. Silva, S. Wijesundara, & N. Atapattu (Eds.), *Invasive alien species in Sri Lanka – Strengthening capacity to control their introduction and spread* (pp. 27–38). Biodiversity Secretariat, Ministry of Environment.

Zhuang, S., Hao, C., Feng, J., & Zhang, X. (2010). Active antifungal components of *Mikania micrantha* HBK. *Journal of Zhejiang University: Agriculture and Life Sciences, 36*(3), 293–298.

Publications

Karunarathna, T. C. M. F., Damunupola, J. W., & Bandara, B. M. R. (2020). *Antifungal activity of six invasive plant extracts against Fusarium sp. isolated from Dracaena sanderiana leaf spots.* In *Proceedings of the International Conference of the Indian Phytopathological Society* (Vol. 7). New Delhi, India.

Karunarathna, T. C. M. F., Damunupola, J. W., & Bandara, B. M. R. (2019). *Antifungal activity of Mikania micrantha H.B.K. (Asteraceae) extracts against fungal phytopathogens in the floriculture industry.* In *Proceedings of the International Forestry and Environment Symposium* (Vol. 24, p. 20). Sri Lanka.

Karunarathna, T. C. M. F., Damunupola, J. W., & Bandara, B. M. R. (2018). *Screening of selected invasive plant extracts for antifungal activity against Colletotrichum gloeosporioides.* In *Proceedings of the International Research Symposium on Pure and Applied Sciences* (Vol. 3, p. 21). Sri Lanka.

Karunarathna, T. C. M. F., Damunupola, J. W., & Bandara, B. M. R. (2017). *Antifungal activity of Mikania micrantha Kunth (Asteraceae) and Clidermia hirta (L.) D. Don. (Melastomataceae) plant extracts.* In *Proceedings of the PGIS Research Congress* (Vol. 4, p. 112). Sri Lanka.

Thesis reference

Karunarathna, T.C.M.F. (2024). Screening selected invasive plant extracts/ compounds for antifungal activity against pathogens of ornamental foliage plants. M.Phil. Thesis, Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

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EFFECT OF TEACHER PEDAGOGICAL ASPECTS ON SECONDARY STUDENTS' INTRINSIC MOTIVATION, ASPIRATIONS, SELF-CONCEPT AND ACHIEVEMENT IN SCIENCE

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Science is everywhere; even this paper is not possible without science. Science is a critical area as it focuses on meeting basic human needs by laying the necessary foundation in diverse fields. Science education refers to the systematic study and teaching of scientific concepts, principles and methods to develop and understanding of the natural world and foster critical thinking, problem solving and decision-making skills. It encompasses both the theoretical knowledge of subjects like Biology, Chemistry and Physics and practical applications through experimentation and inquiry-based learning. In the 21st century, teachers' role is a complex and difficult in line with rapid changes in the school environment driven by advances in science and technology, changing demographics, globalization and the environment. Thus, in the 21st century, teacher competence goes beyond the ability to teach well. Professional teachers are expected to be continuous learners, agents of school change, and individuals who can build and nurture relationships to enhance the quality of learning within the school.

Based on the above, science teaching should inspire students' curiosity and shift the emphasis from merely knowing facts to fostering innovation and creativity in applying ideas. Therefore, teacher has a major responsibility to enhance science education in order to build up the scientific literacy of society.

Over the last few decades, researchers from many different disciplines have been trying to identify the factors that contribute to students' reluctance to enter science-related fields in order to reduce barriers in approaching corresponding occupations. Academic motivation is important to enhance students' interest and performance in science. Intrinsic motivation and extrinsic motivation are the major types of motivation that affect students' performance according to the Self-Determination Theory. Intrinsic motivation involves teachers providing choice enabling students to set goals and investigate their interests

and curiosities. Furthermore, educational aspiration is the cumulative result of various levels of aspiration, including career goals, occupational ambitions, lifestyle preferences, and the desire for wealth. Every student has educational aspirations. It is a decision which the individual makes about what he wants to become in life and what courses he or she wants to study. Science understanding and ability also enhance the capability of all students to hold meaningful and productive jobs in the future. The future world requires entry level workers with the ability to learn and reason, think creatively, make decisions and solve problems according to the scientific method. Thus, career aspiration is a very important aspect for the persistency of economy in the country.

In Sri Lanka the junior secondary school curriculum focuses on promoting student-centered learning by giving more autonomy to both students and teachers in the learning and teaching process. In order to give teachers more autonomy, they are encouraged to select proper teaching practices, learning resources, and assessment methods in order to ensure that students attain their learning outcomes.

At the secondary level students are encouraged to take ownership of their learning and personal goals. As they prepare for the G. C. E. (O/L) examination, the intrinsic motivation to succeed becomes more apparent. Factors such as self-driven interest in subjects, the desire for personal achievement, and the realization of future opportunities motivate students to put in consistent effort. This gradual enhancement of intrinsic motivation not only help student perform well in exams, but also the foundation for life-long learning. Thus, the selected Grades were 8 and 9 for this study.

Further, the development of a strong science self-concept is crucial for secondary level students as it significantly influences their academic performance, career aspirations, and overall confidence in science-related tasks. A positive science self-concept allows students to view themselves as capable and competent in understanding and applying scientific concepts which fosters a deeper interest in the subject. During the secondary level, students are exposing to more advanced scientific topics and practical experiments, which can either strengthen or weaken their self-perception depending on their experiences and encouragement. Teachers and parents play a vital role in nurturing this self-concept by providing positive reinforcement, addressing misconceptions and creating a supportive learning environment in Sri Lanka. A well-developed science self-concept not only enhances students' motivation to pursue science but also prepare them for future challenges in an increasingly science-driven world.

Methodology

The aim of this study was to investigate the effect of teacher pedagogical aspects on secondary students' intrinsic motivation, aspirations, self-concept and achievement in science to enhance the science education in Sri Lanka. The mixed methods approach used in this study has provided both quantitative and qualitative perspectives to measure psychological aspects of students and teachers and their effects on science education. Understanding both perspectives has enabled triangulation of findings in order to maintain a greater confidence in the results to draw conclusions.

Results and Discussion

The findings revealed a significant improvement in all four factors: intrinsic motivation, aspiration, self-concept and achievement. Therefore, it can be concluded that the student-centered teaching-learning methodologies and strategies applied in the intervention for the experimental group have enhanced students' intrinsic motivation, aspiration, self-concept, and achievement in science. Accordingly, the teacher selected pedagogical aspects directly affect the students' intrinsic motivation, aspiration, self-concept and achievement in science.

As the country strives to cultivate a scientifically literate and innovation-driven workforce, understanding how teaching methods affect students' internal drive and self-belief is essential. The findings can help improve classroom practices, inform teacher training programmes

and guide curriculum reforms to foster a more engaging and inclusive science learning environment.

Conclusion

This research supports equitable access to quality science education. Ultimately it contributes to building a generation of students who are not only competent in science but also inspired to pursue scientific careers that align with Sri Lanka's future socio-economic needs.

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Selected References

Chandrasena, W. D. (2013). *Seeding science success: Relations of secondary students' science self-concepts and motivation with aspirations and achievement* (Doctoral dissertation, University of Western Sydney, Australia).

Deci, E. L., & Ryan, R. M. (1981). Curiosity and self-directed learning: The role of motivation in education. *Contemporary Educational Psychology, 6*(4), 307–323. https://doi.org/10.1016/0361-476X(81)90010-9

Deci, E. L., & Ryan, R. M. (1985). The general causality orientations scale: Self-determination in personality. *Journal of Research in Personality, 19*(2), 109–134. https://doi.org/10.1016/0092-6566(85)90023-6

Deci, E. L., & Ryan, R. M. (2002). Self-determination research: Reflections and future directions. In E. L. Deci & R. M. Ryan (Eds.), *Handbook of self-determination research* (pp. 431–441). University of Rochester Press.

Deci, E. L., & Ryan, R. M. (2010). Self-determination. In J. W. Wright (Ed.), *The Corsini encyclopedia of psychology* (4th ed., pp. 1–2). John Wiley & Sons.

Publications

Narangoda, N. W. L., Chandrasena, W. D., & De Silva, W. A. P. P. (2018). *The impact of scientific literacy and motivation of Grade 11 students on their performance in science.* In *Proceedings of the Postgraduate Institute of Science Research Congress, Sri Lanka* (p. 114). Peradeniya, Sri Lanka.

Narangoda, N. W. L., Chandrasena, W. D., & Madawala, H. M. S. P. (2021). *Relations of secondary students' intrinsic motivation and aspirations with their achievement in science. International Journal of Research-Granthaalayah, 10*(9).

Narangoda, N. W. L., Chandrasena, W. D., & Madawala, H. M. S. P. (2021). *Relations of secondary students' intrinsic motivation and aspirations with their self-concept in science. International Journal of Research-Granthaalayah, 10*(9).

Narangoda, N. W. L., Chandrasena, W. D., & Madawala, H. M. S. P. (2022). *Relations of teaching methods with secondary students' intrinsic motivation, self-concept and achievement in science.* In *Proceedings of the International Conference of Science Education* (6th August 2022). University of Peradeniya, Sri Lanka.

Thesis reference

Narangoda, N.W.L., Effect of teacher pedagogical aspects on secondary students' intrinsic motivation, aspirations, self-concept and achievement in science, Ph.D. Thesis, Postgraduate Institute of Science, University of Peradeniya.

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A SYSTEMATIC APPROACH FOR ACCURATE IDENTIFICATION AND TRANSLITERATION OF BRAILLE INTO SINHALA TEXT

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Vision impairment refers to the condition where a person's eyesight cannot be restored to normal levels. This typically involves a reduction in visual clarity, known as the loss of visual acuity, making it difficult to see objects clearly. Additionally, vision impairment may be caused by a loss of the visual field, limiting the eye's ability to see the full surroundings without moving the eyes or head. Vision impairment can be divided into Distance Vision Impairment and Near Vision Impairment. Distance vision impairment is classified as mild, moderate, severe, or blindness based on visual acuity. According to the World Health Organization (WHO), there are approximately 285 million people around the world living with visual impairments, including 39 million who are blind. Among these cases, 43% are due to uncorrected refractive errors, while cataracts are responsible for 33% of all instances of blindness.

Braille is a tactile system used for reading and writing by individuals who are blind or visually impaired. It enables them to read and write through touch. While many people mistakenly believe Braille is a separate language, it is a code that uses specific patterns to represent the letters of the alphabet. Braille has been adapted for numerous languages, including English, French, Spanish, Chinese, German, Arabic, and Italian, as well as several Asian languages such as Sinhala, Tamil, and Hindi.

There are three significant types of Braille codes, Grade 1, Grade 2 and Grade 3, based on the English alphabet specifically. The 26 common alphabet letters and punctuation are covered in Grade 1. Beginners who want to learn Braille often start learning in Grade 1. Grade 2 uses the same letters and punctuation as Grade 1 with the addition of contractions for frequently used words and letter combinations. Contractions save time and space since Braille is large and takes up more space than conventional print. These contractions speed up both reading and writing Braille.

Only personal letters, diaries, and notes commonly utilize Grade 3. The whole words are reduced to just a few letters. Other popular Braille codes include music Braille and Nemeth Braille (for mathematics).

The stylus is used to punch holes in a piece of cardstock paper that has been placed within the slate. The raised dots that will be read by touch are the punched holes. Writing on paper with a pencil requires writing from left to right and forming the letters exactly as they will be read. While writing Braille, the cells must be written in reverse order, and the letters must be written from right to left to be read correctly when the paper is removed from the slate and turned over to reveal the raised dots.

The widely used Braille writing system has 63 characters of one to six raised dots placed in a six-position grid or cell. These Braille characters are embossed in lines on paper. Raised dot patterns in 3 x 2 cells with a limit of six dots each make up a distinct Braille pattern for each letter, as shown in Figure 1.

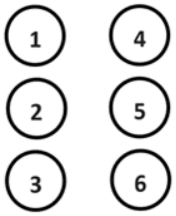

Figure 1. Sample Braille cell

Although Braille is widely used, both reading and writing in Braille remain labor-intensive tasks. For sighted individuals, accurately converting Braille documents into text is especially challenging, as it demands a thorough understanding of Braille symbols and rules. Braille was first introduced in Sri Lanka in 1912 and was later adapted to the more advanced Bharati Braille system in 1947. However, the lack of effective translation tools has led to a communication gap between the visually impaired and sighted populations.

This research aims to address translation challenges by developing a reliable and user-friendly system for converting Sinhala Braille into standard text. By evaluating the proposed solution against the current state of the art approaches, the study strives to bridge communication barriers and enhance accessibility for individuals with visual impairments.

In recent advancements in Braille translation to international languages such as English, Hindi, Tamil, Bengali, and Arabic, Aisha Mousa et al. introduced a Smart Braille System Recognizer for converting Braille into English. Their approach involved using a flatbed scanner to acquire images of single-sided Braille documents, followed by several processing stages including pre-processing, image enhancement, segmentation, feature extraction, and cell recognition. The scanned image is expanded beyond its original form to help restore any broken or distorted parts of the Braille dots. This method achieved a high dot detection accuracy, ranging from 94.39% to 99.76%.

Gadag et al., 2016 contributed in implementing a Braille letter identification system with two phases: Testing and Training. The testing phase included preprocessing, segmentation, feature extraction, and an additional SVM classifier. The SVM classifier was used for character matching and unsupervised classification was used under the SVM classifier to cluster data and classify data based on clusters. Training phases were performed after preprocessing, along with the feature extraction method.

Prakash et al., 2020 introduced a system of Braille Recognition using Convolutional Neural Networks, which followed the steps of pre-processing, segmentation, and image classification. In the preprocessing phase, they have used Circular Hough Transformation for identifying circles. A convolutional neural network (CNN) was used to extract features from the image. CNN used several layers for the above purposes. The system achieves 98.63% accuracy with 20 epochs for a training dataset of 500 sizes.

In the state of the art of Braille conversion to Sinhala text, Braille to Text Converter for Sinhala was introduced by De Silva and Liyanage. They

introduced a multi-step Braille to text converter. The process involved noise removal using grey scaling, character segmentation, and feature extraction by identifying Braille dots and storing them in a binary array. The classification was performed using the k-nearest neighbour (KNN) algorithm, achieving 91.2% accuracy. They noted challenges such as light variations, dark spots, and non-uniform illumination, suggesting improvements with post-processing techniques like dictionaries and grammar checkers.

Perera and Wanniarachchi developed an Optical Braille Translator for Sinhala Braille, focusing on pre-processing handwritten (using a pen) and computer-generated single-sided images through grey scaling, dilation, erosion, subtraction, and global thresholding. They achieved 99% accuracy but faced issues with detailed image acquisition via scanning.

Vasanthapriyan and De Silva introduced a prototype for processing handwritten and typed documents, utilizing Gaussian blur, grayscale, de-skewing, gamma correction, and morphological erosion. Feature extraction was performed using the Otsu threshold method, achieving an accuracy of over 95%. Challenges included image acquisition issues such as shadows and background shading. They proposed using an optical scanner for future improvements.

Each system aimed to improve the accuracy and robustness, addressing challenges in image processing and character recognition. Previous works achieved 95%-99% accuracy with handwritten and computer-generated Braille but 91%-92% with original Braille printed documents. The dataset which was written by using a pen have low availability of anomalies like dust, erased dots and noise and they have higher clarity of the dots to achieve higher accuracy.

The current study was conducted using a small original dataset due to the unavailability of a real proper dataset and the presence of both handwritten (man-made) and computer-generated data. The expansion of dataset will be focused in future.

Methodology

The system was implemented using a set of underrepresented datasets. It assumes input images are in proper orientation, with slanted or misaligned images excluded from this study. Future research will focus on addressing such cases. The system processes images in three main stages: pre-processing, cell segmentation, and letter identification. Figure 2 shows the flow of the process.

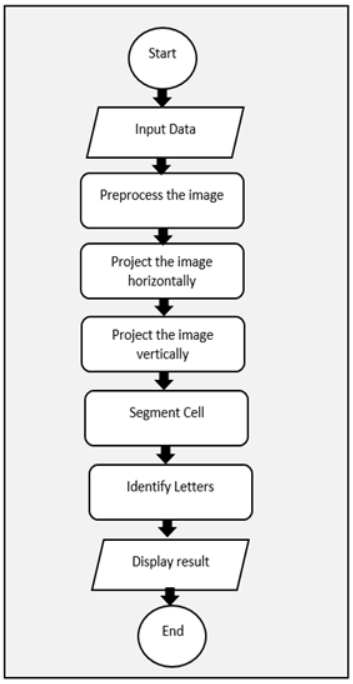

Figure 2. The flow of the proposed system

Pre-processing involves several steps to prepare the images for analysis. In the first step, the original image shown in Figure 3 undergoes enhancement and normalisation to optimize contrast. Next, the input image is processed to enhance feature extraction with several techniques. The system uses several filtering techniques like median, threshold, and mean and finally converts into a grayscale image.

Figure 3. The original image of a Braille Document

Cell segmentation is performed using two major steps, horizontal projection and vertical projection, along with the ROI method.

This step utilizes a letter recognition algorithm that identifies letters in the binary image by processing rectangular regions and comparing them to predefined patterns in the alphabet dictionary, which contains Sinhala letters. A Python dictionary is used to translate vectors of 0s and 1s to characters. A few example patterns in the dictionary are as follows:

repr([1, 0, 0, 0, 0, 0]) : "ඁ",\
repr([1, 0, 1, 0, 0, 0]) : "ඓ",\
repr([1, 1, 0, 0, 0, 0]) : "ඔ",\
repr([1, 1, 0, 1, 0, 0]) : "ඊ",\

Results and Discussion

The dataset includes around 230 Braille characters in 30 Braille image sets. Some of them are properly scanned without alignment issues, and some of them are not. However, all the images were processed through the system's major stages, which are mentioned in the methodology. The final cell segmented image of the original image in Figure 3 is shown in Figure 4.

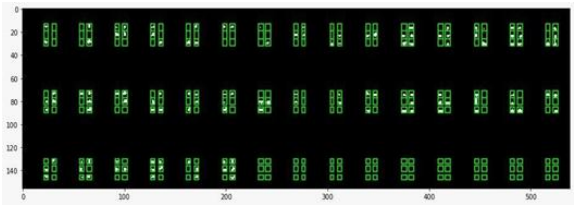

Figure 4. Cell Segmented image

The extracted cell in the first letter in the first row in Figure 3 can be represented in the cell arrangement in Figure 5.

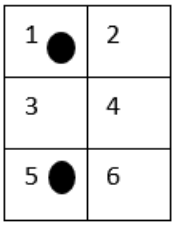

Figure 5. Cell arrangement of dots

The pattern is 100010. Using the Python directory which has the letter representations for a set of sequences of binary, the letter will be identified and displayed on top of the cage of the Braille letter as shown in Figure 6.

Figure 6. Identified "ක" letter in segmented Braille cell

The letters that were generated for the Figure 3 is shown in Figure 7.

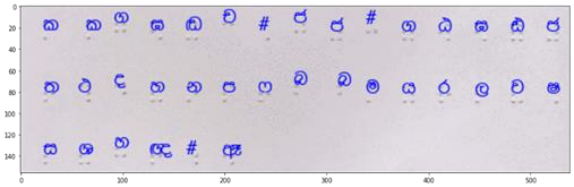

Figure 7. Letters generated from the original Braille image

The number of letters correctly mapped and the percentages of the accuracy of each letter are shown in Table I for the original image in Fig.7. In the table, RN represents the row number of Braille letters in the image. TL represents the total number of letters present in row-wise in the image and AL column represents the letters which identified accurately. Column Percentage shows the percentage of the letters identified correctly within the row.

Table 1: Results of the sample image in Figure 2.

RN	TL	AL	Percentage
R-1	15	11/15	73.3%
R-2	15	14 /15	93.3%
R-3	06	06 /06	100%

The overall accuracy of the letter identification in the image is 86.1%. And the overall system accuracy based on the dataset and its identification is 90%.

Conclusion

In conclusion, prior research has demonstrated high levels of performance, achieving accuracy rates between 95%-99% for handwritten and computer-generated Braille, while comparatively lower rates of 91%–92% were observed with original printed Braille documents. Datasets produced through pen-based writing exhibited limited anomalies such as dust particles, erased or distorted dots, and background noise, thereby offering greater clarity of the Braille patterns and consequently facilitating higher recognition accuracy. The proposed system effectively identifies letters on Braille with an overall accuracy is 90% with the underrepresented dataset of Braille images that maintain proper orientation. The system uses preprocessing techniques like mean, median filtering to reduce the image noise and enhance the image. The use of vertical and horizontal projection profiles for cell separation is a crucial aspect of this methodology. The system demonstrates a high preprocessing capability, emphasizing the importance of dot clarity for accurate letter identification. However, there remains room for improvement in the areas of dot identification and cell segmentation, as these factors are critical to enhancing the accuracy of the final results. Further, the generalizability issue will be solved using an expanded dataset and improve the system's overall efficacy and reliability. Additionally, in future work, it is suggested to fine tune the system by expanding the dataset without considering orientation issues or by adapting sequence learning methods like transformers or graph neural network and techniques like Siamese network to improve both accuracy and validation of the results.

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Selected References

De Silva, N. M. T., & Liyanage, S. R. (n.d.). *Sinhala Braille translator. International Journal of Trend in Research and Development.* http://www.ijtrd.com

Gadag, M., & Hudayashankara, V. (2016). *Generation of English text from scanned Braille document. International Journal of Engineering Science and Computing, 6*(8), 4446. https://doi.org/10.4010/2016.1021

H, P. T. D. S., & L, W. W. K. I. (2018). *Optical Braille translator for Sinhala Braille system: Paper communication tool between vision impaired and sighted persons. The International Journal of Multimedia & Its Applications, 10*(1/2/3), 29–43. https://doi.org/10.5121/ijma.2018.10303

Iowa Department for the Blind. (n.d.). *How to read or write Braille.* https://blind.iowa.gov/educators/how-read-or-write-braille

Mousa, A., Hiary, H., Alomari, R., & Alnemer, L. (2013). *Smart Braille system recognizer. International Journal of Computer Science Issues.* http://www.IJCSI.org

Pascolini, D., & Mariotti, S. P. (2012). *Global estimates of visual impairment: 2010. The British Journal of Ophthalmology, 96*(5), 614–618. https://doi.org/10.1136/bjophthalmol2011300539

Prakash, S., Thomas, S., & Gopalan, S. M. (2020). *Braille recognition using convolutional neural networks. Volume XVI*(206), 206–214.

Roar Media Archive. (2020, January 7). *Touching words: A few things you need to know about Braille in Sri Lanka.* https://roar.media/english/life/in-the-know/braille-in-sri-lanka

University of Pittsburgh, Department of Ophthalmology. (n.d.). *What is vision impairment?* http://ophthalmology.pitt.edu/visionimpairment/what-vision-impairment

Vasanthapriyan, S., & D. Silva, M. (2019). *Optical Braille recognition software prototype for the Sinhala language. Advances in Science, Technology and Engineering Systems Journal, 4*(4), 221–229. https://doi.org/10.25046/aj040427

World Health Organization. (2023, August 10). *Blindness and vision impairment.* https://www.who.int/newsroom/factsheets/detail/blindness-and-visual-impairment

Publications

Dampalessa, D. R. C. G. K., & Ragel, R. G. (2025). *Identification and transliteration of Braille letters into Sinhala text.* In *Proceedings of the 5th International Conference on Advanced Research in Computing (ICARC)* (pp. 1–6). Belihuloya, Sri Lanka. https://doi.org/10.1109/ICARC64760.2025.10963204

Thesis reference

Dampalessa, D.R.C.G.K. (2025). A Systematic Approach for Accurate Identification and Transliteration of Braille into Sinhala Text. Master's Thesis, Postgraduate Institute of Science, University of Peradeniya.

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AN INTERPRETABLE MACHINE LEARNING MODEL TO PREDICT DRUG ADDICTION AMONG CHILDREN IN SRI LANKA

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Drug addiction is a serious problem in Sri Lanka, especially among young people. Common drugs include heroin, cannabis (ganja), and methamphetamine (ice). Most drug-related arrests happen in the Western Province, especially in Colombo, Gampaha, and Kurunegala. In 2022, over 152,000 people were arrested for drug use, and many were between the ages of 15 and 25. A study also showed that some school children have already tried cigarettes, alcohol, or drugs. Children may start using drugs due to family issues, bad friendships, stress, school problems, or not knowing the dangers. If a child is randomly exposed to different factors that contribute to substance abuse, the proposed solution can predict whether the child is at risk of drug addiction.

This study further intends to provide a way for parents and educators to determine whether a child is susceptible to drugs and, if so, to identify possible solutions that may prevent exposure. The proposed approach examines how home, school, and social environments influence the likelihood of drug use among school children, and to develop a representative dataset based on these factors. Covering all districts of Sri Lanka, this study centers on school-aged children. Although some data have been collected from adults, the emphasis is placed on recalling their experiences during childhood.

The general objective of the Drug Abuse Monitoring System (DAMS) is to establish a reliable database for effective planning and monitoring of drug abuse, addiction and trafficking. The specific objectives of the reporting system are to deter-mine the incidence, prevalence, and characteristics of drug users who come into con-tact with reporting institutions, doctors, and police. It also aims to monitor the trends and patterns in drug use over time. Additionally, the system seeks to identify and describe the at-risk groups within the population. Another key objective is to assess and evaluate existing treatment and rehabilitation programs for drug users. Finally, the reporting system serves as

an "early warning system" to enable timely program responses to emerging drug-related issues.

Although street children in India represent a large and vulnerable group, few academic studies focus specifically on substance abuse in this population. Most existing re-search explores causes, effects, and risk factors, while studies on preventive strategies are limited. However, some preventive insights are available through reports by government and non-governmental organizations.

Various researchers have applied machine learning (ML) to predict drug abuse risk and addiction outcomes. Han et al. developed ML models to predict opioid mis-use among U.S. adolescents using the National Survey on Drug Use and Health (2015–2017, adolescents aged 12–17). They trained artificial neural networks, a distributed random forest, and gradient boosting machines, comparing them against penalized logistic regression. All models performed similarly (AUC-ROC of 0.81), but the distributed random forest achieved the highest precision-recall performance. This study demonstrated that ML techniques can successfully identify the relatively rare cases of adolescent opioid misuse with good accuracy.

Methodology

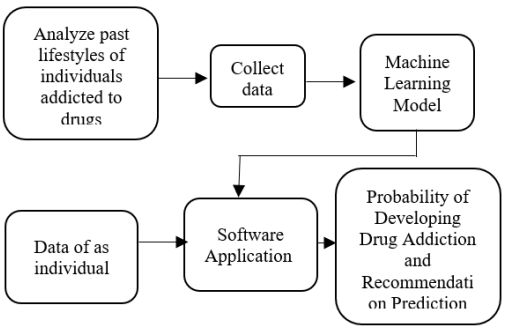

Figure 1. Overview of the proposed approach.

This section outlines the procedures followed for collecting data to train and validate the proposed machine learning model for predicting drug addiction among children in Sri Lanka. The process included defining the study population, designing and administering a questionnaire, obtaining required institutional permissions, addressing ethical concerns, and ensuring data confidentiality.

Two groups were involved:

- Case group: 500 individuals with a history of drug addiction, selected from various government and NGO rehabilitation centers.

- Control group: 500 non-addicted individuals from the general public, including school children and adults across multiple regions.

Data were collected through paper-based surveys and Google Forms in collaboration with participating schools, a technical college, and rehabilitation centers. The participants included 350 students under 22 years of age from multiple schools and a technical college in the Kurunegala district, of which 200 responses were collected via Google Forms, and 520 individuals from two rehabilitation centers. Questionnaire Design. A structured questionnaire was developed to gather demo-graphic, familial, social, and behavioral data related to drug addiction risk. Administered mainly in Sinhala, it included yes/no questions for clarity and ease of analysis. The questionnaire, reviewed by experts and individuals with addiction experience, covered personal background, parental influence, peer and school environment, and drug exposure factors to identify potential addiction predictors among school children.

Ethical clearance and institutional permissions were obtained before data collection began. Verbal consent was obtained from all participants after clearly explaining the study's purpose and voluntary nature. For minors and institutionalized individuals, data collection proceeded only with guardian or institutional approval. No personally identifiable information was collected.

Data collection was conducted in phases:

- At rehabilitation centers, group sessions were held with motivational talks by professionals. Trained facilitators assisted participants with literacy challenges.
- In schools, questionnaires were distributed after awareness sessions that emphasized confidentiality and honesty. Children engaged in recreational activities before and after completing the survey to reduce discomfort.
- Participants with literacy difficulties or language barriers were interviewed verbally by trained staff.

All responses were anonymized—no names, ID numbers, or traceable personal details were recorded. Data were collected individually and securely stored. For minors, interviews were conducted in private, ensuring both comfort and confidentiality.

The overall design of the machine learning model is shown in Figure 2 and involves several key steps: data preprocessing, data splitting, model selection, evaluation, tuning, and final verification. First, the collected data were cleaned and prepared for machine learning. All features were converted into numerical values mostly as binary (0 or 1), while the province attribute was coded from 1 to 9. The final dataset included 54 features and a total of 947 valid records. Missing values were handled, and label encoding was used to convert text-based categories into numbers, including the target variable (addicted or not). Next, the dataset was split into three parts: 50 records (5%) were kept aside for final verification, while the remaining 897 records were divided into 627 for training and 270 for testing the model. This 70:30 ratio was chosen based on experimental results to evaluate the model's generalization ability. Four supervised machine learning algorithms Random Forest, Decision Tree, Support Vector Machine (SVM), and Logistic Regression were trained and compared to identify the best-performing classifier. Their performance was tested on the testing set, and hyperparameter tuning was done to improve results. Finally, the best model was tested on the 50 untouched records to verify its accuracy on new, unseen data.

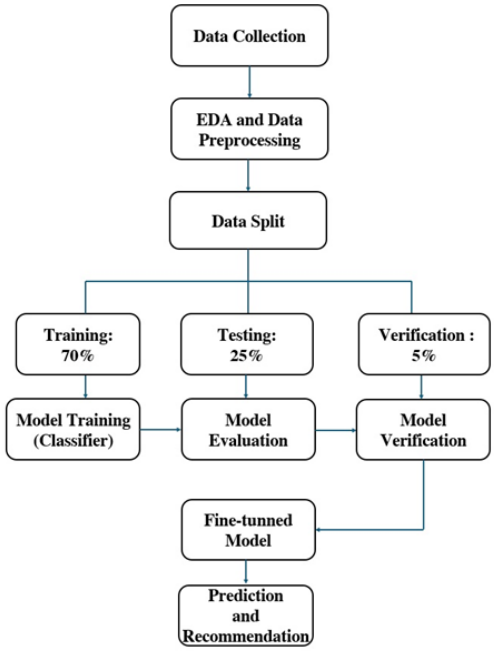

Figure 2. The main steps of the machine learning model

To identify the best classification model for predicting drug addiction risk, four different machine learning models were tested: Random Forest, Support Vector Machine (SVM), Logistic Regression, and Decision Tree. These models were chosen because they represent different types of algorithms. Before training, the input features were standardized or normalized to improve model performance. All models were built using the scikit-learn library in Python. The Random Forest model was created using the Random Forest Classifier, and the SVM model was built using the SVM .SVC class, using both a linear kernel and the default RBF kernel. Logistic Regression was implemented with the Logistic Regression class, keeping the default settings for regularization. The Decision Tree model used the Gini index to measure the quality of splits. Among the tested decision tree types ID3, C4.5, and CART the CART algorithm was selected for its better performance. After selecting the best-performing model, a user-friendly software application was developed using Python's Tkinter library. The application

integrates the trained machine learning model and includes interfaces in both Sinhala and Tamil, making it easy for users from different language backgrounds to use. This tool allows individuals to assess their risk of drug addiction without needing technical knowledge. Example screenshots of the application are included in the Results and Discussion section.

Results and Discussion

Descriptive Statistics. Figure 3 presents descriptive insights into the profiles of drug-addicted individuals based on questionnaire data. Most addicts were from the Western Province (68%) and born after 1990 (61%), indicating both regional and generational patterns. A significant behavioral trend was noted, with 92% being disobedient to teachers. Males overwhelmingly dominated the dataset (97%), while only 3% were female.

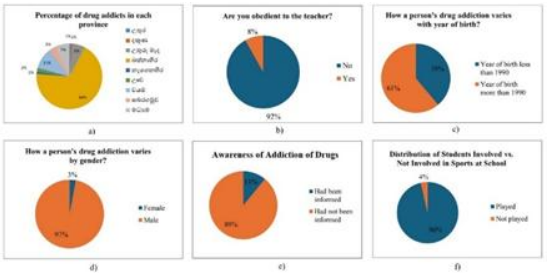

Figure 3. Descriptive statistics of the dataset obtained through the questionnaire. Distribution of participants: (a) drug addiction across the nine provinces, (b) obedience to teachers, (c) by year of birth, (d) by gender, (e) awareness of drugs, and (f) involvement in sports.

Accuracy, Precision, Recall and F1-score of the Models. The performance of the proposed classification model was evaluated using accuracy, precision, recall, and F1-score, with particular emphasis on minimizing false positives and false negatives due to the sensitive nature of the prediction task. Four classifiers were evaluated based on accuracy, all exceeding 98% (See Table 1).

Although performance differences were minimal, the Decision Tree was chosen as the final model due to its superior accuracy, simplicity, interpretability, and computational efficiency.

Table 1. Accuracy, Recall, Precision and F1-score of the four classification models.

Classifier	Accuracy (%)	Recall	Precision	F1-Score
Random Forest	98.943	0.990	0.990	0.990
Support Vector Machine	99.295	0.990	0.990	0.990
Logistic Regression	99.295	0.980	0.990	0.990
Decision Tree	**99.647**	**0.990**	**1.000**	**0.995**

Receiver Operating Characteristic (ROC) Curves. ROC curves for all four models show strong class separability, with near-perfect performance. The Decision Tree achieved the best AUC, indicating slightly superior discriminative ability compared to the others.

Final Decision Tree Generated by the CART Algorithm. To identify the best Decision Tree algorithm, ID3, CART, and C4.5 were evaluated. CART achieved the highest accuracy (99.647%), outperforming ID3 (99.230%) and C4.5 (98.000%), and was selected for the final model due to its superior accuracy and efficiency. The best split was determined using the Gini impurity index. As shown in Figure 6, the decision tree predicts drug addiction based on behavioral and socio-demographic features. The root node, “Are you obedient to the teacher?”, was selected for its highest information gain (Gini impurity of 0.497). Attributes such as obedience, drug awareness, aggression (fighting), parental presence, and sports engagement all contribute to the classification decision. Notably, leaf nodes with low Gini values (close to 0) indicate highly pure classification outcomes.

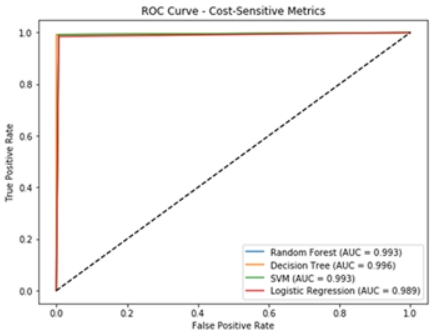

Figure 4. ROC values of the four classification models used.

Model Verification. For evaluation purposes, the final decision tree model was run on a predefined dataset of 50 instances. The final CART decision tree model shown in Figure 6 was applied to the 50 instances. The model classified all 50 instances correctly providing a verification accuracy of 100%.

Sample interfaces from the user interface designed for drug addiction risk assessment are provided in Figure 6. The interface presents a sequence of yes/no questions aligned with predefined input fields. Each question includes a pair of radio buttons allowing users to select one of two options. Once the responses are entered, the user can submit the data using clearly labeled action buttons, after which the system processes the input through the underlying machine learning model and displays the prediction result in a dialog box.

The results demonstrate the high potential of machine learning models in accurately classifying individuals at risk of drug addiction using socio-demographic and behavioral features. The study successfully identifies key behavioral indicators such as obedience, awareness, aggression, and sports involvement that contribute meaningfully to risk classification, providing recommendations for prevention and intervention strategies. Among the evaluated models, the Decision Tree classifier achieved the highest accuracy (99.647%) along with the best F1-score (0.995), indicating a strong balance between precision and recall. Further the model verification accuracy achieved 100%. The final model is both interpretable and efficient, making it suitable for real-world deployment in educational, social or counseling environments where explainability and rapid decision-making are crucial.

Conclusion

This study presents an interpretable machine learning model to predict drug addiction risk among school-aged children in Sri Lanka, using behavioral, social, and familial data. The Decision Tree model achieved high accuracy and F1-score, indicating strong predictive performance. The high accuracy and low misclassification rates underscore the reliability of the proposed framework for real-world deployment. A user-friendly software tool was also created to support practical application in educational and healthcare settings. While limitations such as demographic imbalance and self-reported data exist, this research offers a valuable foundation for data-driven public health strategies aimed at preventing youth substance abuse, especially in underserved communities. Future work can address these issues by expanding the dataset to include a more balanced population across regions and genders, incorporating continuous addiction severity measures, and exploring additional models such as ensemble methods or deep learning techniques. The user interface could be extended to support more languages and platforms, including mobile interface.

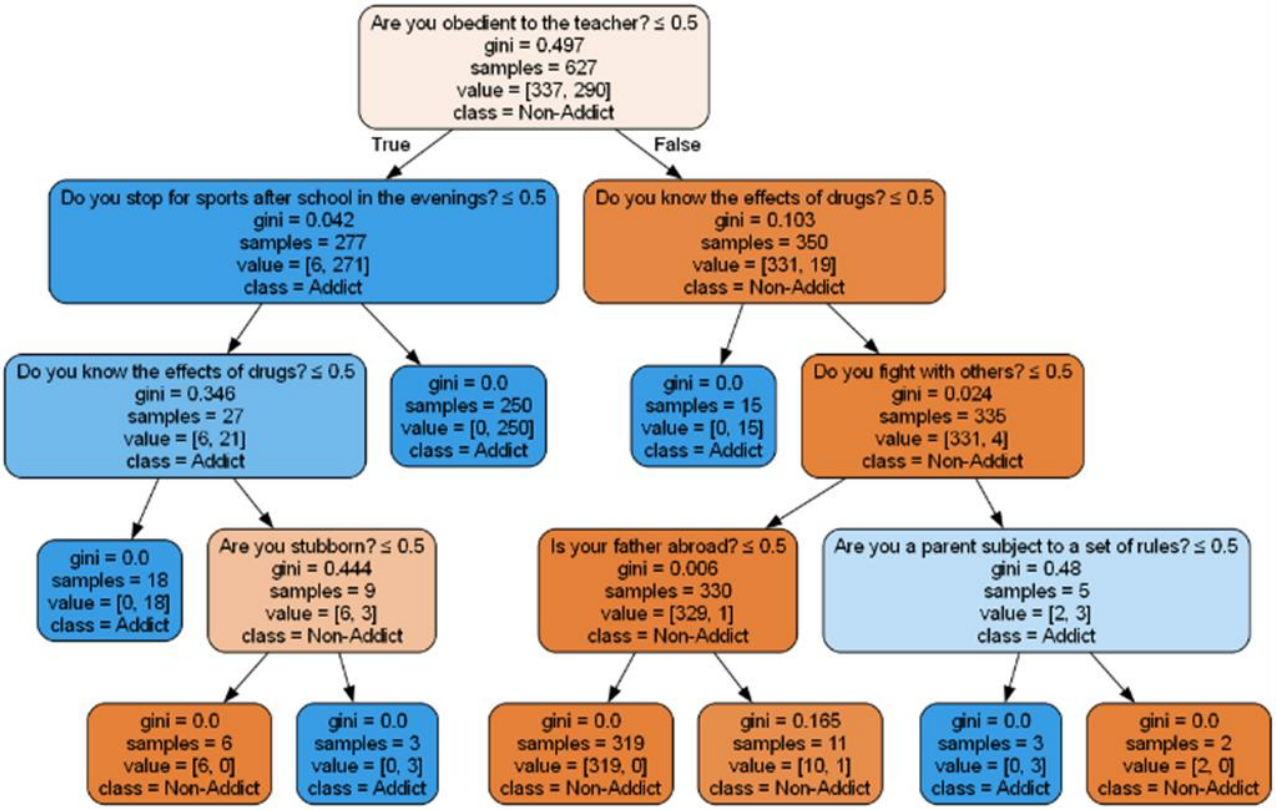

Figure 5. Visualization of the final CART decision tree model

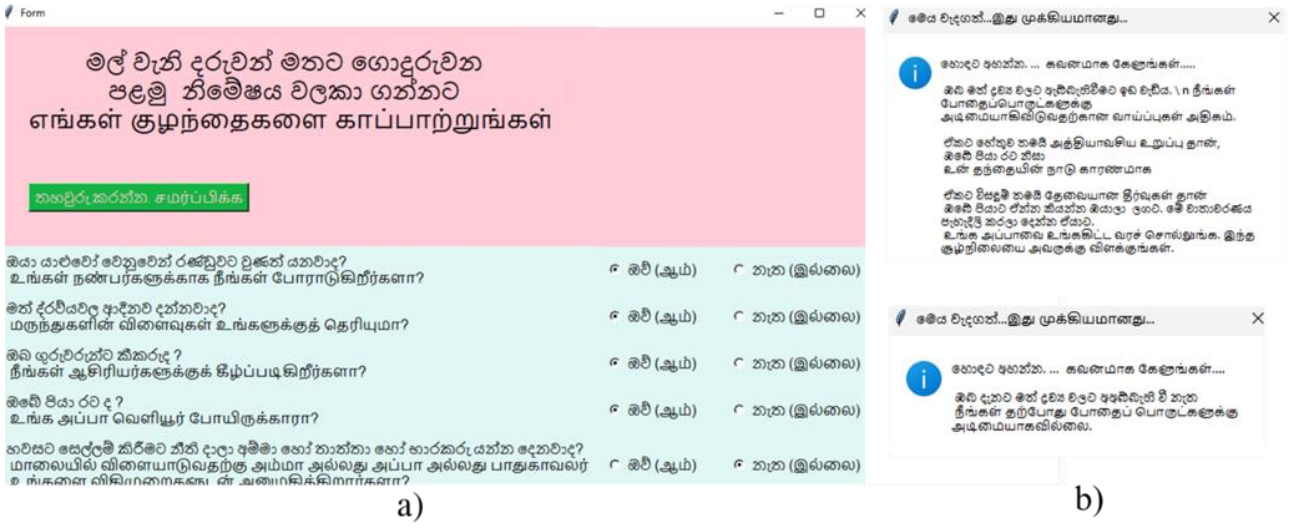

Figure 6. Sample user interfaces. a) Drug risk assessment questions and b) Recommendation of the machine learning model

Selected References

Abesingha, S., & Bandara, S. A. (2019). *National prevalence survey on drug use 2019.* National Dangerous Drugs Control Board. https://www.nddcb.gov.lk/Docs/annual_report/03%20NDDCB%202019%20%20English.pdf

Han, D.-H., Lee, S., & Seo, D.-C. (2020). Using machine learning to predict opioid misuse among U.S. adolescents. *Preventive Medicine, 130*, 105886. https://doi.org/10.1016/j.ypmed.2019.105886

National Dangerous Drugs Control Board. (2019). *Drug abuse monitoring system 2019 annual report.* Research Division. https://www.nddcb.gov.lk/Docs/research/Annual%20Report%202019.pdf

Njord, L., Merril, R. M., Njord, R., Lindsay, R., & Pahano, J. D. R. (2010). Drug use among street children.

Senanayake, B., & Welagedara, L. (2019). *Drugs related statistics – 2019.* Research Division, National Dangerous Drugs Control Board, Ministry of Defence. https://www.nddcb.gov.lk/Docs/research/Drug_Related_Statistics_2019.pdf

Thesis reference

Manathunga, A.N.D.S. (2024). An interpretable machine learning model to predict drug addiction among children in Sri Lanka. M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

BIRD SPECIES CLASSIFICATION USING STATISTICAL FEATURE ANALYSIS OF AVIAN FLIGHT CALLS

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Birds are vital indicators for biodiversity monitoring and play an important role in maintaining the natural ecosystem balance. They also influence the development of the urban green spaces. Over the past few decades, with the advancement of technology and progress of society, bird species diversity has declined, leading to the extinction of some species . The data from the World Bank in 2018 indicates that out of 4584 bird species globally, 160 are threatened with extinction, mainly due to illegal hunting and habitat changes.

The identification and classification of bird species are therefore crucial in various fields such as conservation, ecology, and ornithology. Birds also contribute to agriculture, landscape formation, coral reef ecosystem, and more. Ornithology, the scientific study of birds, and encompasses bird ecology, evolution, physiology, and the habitats. Bird identification is important not only for ornithologists but also for the wider public.

Traditionally, three main features: morphological characteristics, behavioral characteristics, and birdsong have been used to classify birds. Among these, vocalizations have become a key focus in the automated classification of species, as they often differ from typical songs and calls. . These unique vocalizations allow researchers to recognize bird species by sound alone. However, many birds produce flight calls while migrating, enabling their identification even in dark environments. This study aims to evaluate the effectiveness of statistical feature extraction methods for bird identification.

The manual methods of analyzing large amounts of bird data are significantly challenging due to the time-consuming nature and the potential human error. It needs trained experts who must listen and categorize each bird call in existing manual classification methods. This traditional exercise is not only labor-intensive but also highly subjective. When distinguishing between similar species, experienced researchers also

struggle to differentiate minor variations in flight calls. For instance, the difference between warblers and sparrows poses considerable difficulty in human-based analysis. These issues can lead to inaccurate and inconsistent classifications. Especially when large datasets are used, the automated systems can analyze bird calls more accurately than existing ordinary methods. The automated identification and classification of bird species plays a vital role in various scientific and conservation efforts.

Figure 1. Selected Bird Species in the Dataset

Methodology

This study focuses on three research questions (RQ) aimed at classifying bird species, with the main objective being to identify the most effective machine learning model, supported by an exploration of statistical feature extraction methods and supervised classification techniques.

1. RQ1: Extracting the statistical features from bird sounds.
2. RQ2: The classification of birds using supervised machine learning methods.
3. RQ3: Selection of the best model to classify bird sounds.

The study uses CLO-43SD dataset which has multi-class species identification in avian fight calls. There were 5428 audio clips of flight calls from 43 different species of North American wood warblers (in the family Parulidae). These recordings came from different conditions and were obtained from highly directional shotgun microphones. The omnidirectional microphones are used to record flight calls in noisy backgrounds. All clips were trimmed to contain a single flight call of 43 types of species.

Results and Discussion

Table 1. Extracted statistical features of a bird audio files

Species	**No of samples**	**Length**	**M.RMSE**	**Sum.ZCR**
AMRE	4474	0.2016	0.02138	812
AMRE	4529	0.1709	0.02138	1594
Species	**M.CHROMAGRAM**	**Mean_ CHROMAGRAM_FT**	**M.CQT**	**M.TEMPO**
AMRE	0.386715	0.5607	0.41819	117.45
AMRE	0.388345	0.5406	0.79161	117.45
Species	**Mean_ spectral centroid**	**M. Spectral _Contrast**	**M.MFCC**	**SD_ MFCC**
AMRE	3738.052	18.6438	2.3083	17.068
AMRE	4788.984	15.0240	2.7683	17.363

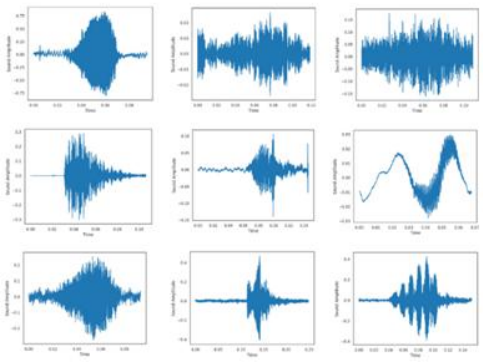

Figure 2. Time amplitude plots

Figure 2 illustrates various patterns of bird species over time and amplitude. The data reveals that bird calls vary depending on the species.

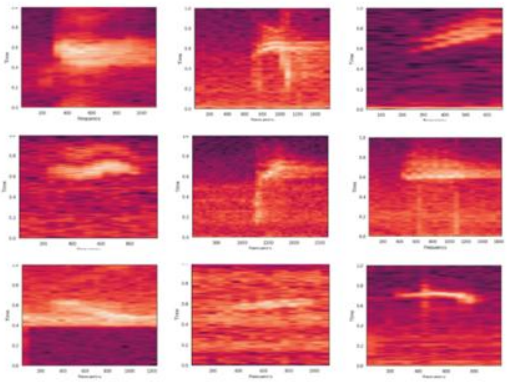

Figure 3. The spectrograms of bird audio files

Figure 3 illustrates the spectrum of frequencies of audio signals of Avian flight calls. Those visually represent the power of different frequencies changes over the time. The amplitude or intensity of the signal at each frequency is represented by the color or brightness of each point on the graph.

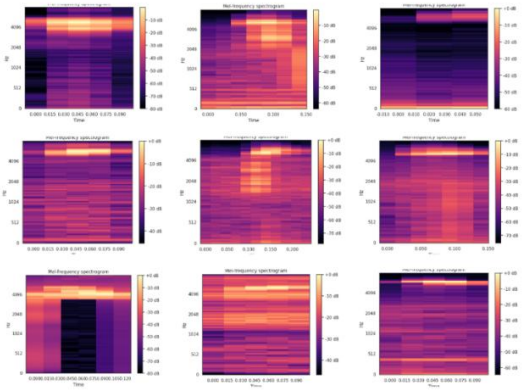

Figure 4. The mel-spectrograms of bird audio files

Figure 4 depicts Mel-spectrograms of Avian bird calls. The frequencies are converted to the Mel scale, which is a perceptual scale of pitches that approximates how humans hear sound. The above graphs vary from audio file to file.

Table 2. The accuracies, kappa statistics, and 95% confidence interval of four machine learning models.

	Accuracy		**Kappa**		**95% Confidence Interval**	
Classification Methods	**With all Features**	**With three important features**	**With all Features**	**With three important features**	**With all Features**	**With three important features**
RF	0.9922	0.9923	0.9920	0.9921	0.9907,09935	0.9908,0.9936
CT	0.9116	0.9050	0.9094	0.9027	0.9071,0.9159	0.9004,0.9095
SVM	0.3422	0.2360	0.3265	0.2178	0.3348,0.3495	0.2295,0.2426
NB	0.2256	0.2014	0.2072	0.1824	0.2192,0.2322	0.1952,0.2077

Table 2 depicts the accuracies, Kappa Statistics, and 95% Confidence Interval of four machine learning models. It is identified that the RF and CT models with all statistical features provide high accuracies at 0.9922 and 0.9116, respectively. According to the Boruta analysis, the mean of MFCC, the standard deviation of MFCC, and the number of samples were selected as important features for classification. Since it is obtained, the accuracy is 0.9920 from RF and 0.9027 from CT. The Kappa statistics are also higher in the above classification techniques. The SVM and NB classifiers presented low accuracies compared to RF and CT.

The extracted statistical features Such as, the number of samples, length of the audio file, Mean Root Square Error, Sum of Zero Crossing Rate, Mean Chromogram, Mean Chromogram Fourier Transform, Mean CQT, Mean Tempo, Mean Spectral Centroid, Mean Spectral Contrast, Mean Mel Frequency Cepstral Coefficient and Standard Deviation of Mel Frequency Cepstral are used for classification. A data imbalance was observed, and an up-sampling approach was applied to generate a balanced dataset for analysis. Further, four supervised machine learning methods were applied to the training set, and the models were validated using the testing set. These classification techniques are conducted in two ways.

Random forest and classification methods are obtained with high accuracies compared to support vector machines and naive Bayes classifiers at 99.22% and 91.16%. These two methods also generate the accuracies in the intervals (0.9907, 0.9935) and (0.9071,0.9159). The Kappa statistics for both methods were above 90% indicating the adequacy of the models. The Boruta analysis extracted three important variables namely, the number of samples, Mean Mel Frequency Cepstral Coefficient, and SD_MFCC. The previous classification methods are conducted on the newly selected variables and obtain the following results. As, in the above case, Random Forest and Classification Tree provide accuracies at 99.23% and 90.50% respectively, where the Kappa values are greater than 90% as well. The confidence intervals for these two methods are (0.9908, 0.9936) and (0.9004,0.9095) which shows a high accuracy range. Overall, two methods illustrate high results compared to SVM and NB classifiers. Therefore, this study indicates that RF and CT techniques are the best methods that can be used to classify bird sounds in the present study and future investigations of birds.

Selected References

Ahlén, I., & Baagøe, H. J. (n.d.). *Use of ultrasound detectors for bat studies in Europe: Experiences from field identification, surveys, and monitoring.*

Andono, P. N., Shidik, G. F., Prabowo, D. P., Pergiwati, D., & Pramunendar, R. A. (2022). *Bird voice classification based on combination feature extraction and reduction dimension with the K-nearest neighbor. International Journal of Intelligent Engineering and Systems, 15*(1), 262–272. https://doi.org/10.22266/IJIES2022.0228.24

Atanbori, J., Duan, W., Shaw, E., Appiah, K., & Dickinson, P. (n.d.). *Classification of bird species from video using appearance and motion features.* Sheffield Hallam University Institutional Repository. http://shura.shu.ac.uk/22060/

Austin, V. I., Dalziell, A. H., Langmore, N. E., & Welbergen, J. A. (2021). *Avian vocalisations: The female perspective. Biological Reviews, 96*(4), 1484–1503. https://doi.org/10.1111/brv.12713

Gayk, Z. G., Simpson, R. K., & Mennill, D. J. (2021). *The evolution of wood warbler flight calls: Species with similar migrations produce acoustically similar calls. Evolution, 75*(3), 719–730. https://doi.org/10.1111/evo.14167

Hu, S., Chu, Y., Wen, Z., Zhou, G., Sun, Y., & Chen, A. (2023). *Deep learning bird song recognition based on MFF-ScSEnet. Ecological Indicators, 154,* 110844. https://doi.org/10.1016/j.ecolind.2023.110844

Pimm, S., Raven, P., Peterson, A., & Ehrlich, P. R. (2006). *Human impacts on the rates of recent, present, and future bird extinctions.* BirdLife

Data Zone. http://www.birdlife.org/datazone/species/index.html

Salamon, J., Bello, J. P., Farnsworth, A., Robbins, M. B., & Kelling, S. (2016). *Towards the automatic classification of avian flight calls for bioacoustic monitoring. PLOS ONE, 11*(11), e0166866. https://doi.org/10.1371/journal.pone.0166866

Sanders, C. E., & Mennill, D. J. (n.d.). *Acoustic monitoring of migratory birds over western Lake Erie: Avian responses to barriers and the importance of islands.* University of Windsor ScholarWorks. https://scholar.uwindsor.ca/biologypub

Sæther, B. E., Engen, S., Lande, R., Saether, B.-E., & Lillegård, M. (2005). *Time to extinction of bird populations. Ecology, 86*(3), 693–700. https://doi.org/10.1890/04-0878

Stowell, D., Wood, M. D., Pamuła, H., Stylianou, Y., & Glotin, H. (2019). *Automatic acoustic detection of birds through deep learning: The first Bird Audio Detection challenge. Methods in Ecology and Evolution, 10*(3), 368–380. https://doi.org/10.1111/2041-210X.13103

Van Doren, B. M., et al. (n.d.). *Automated acoustic monitoring captures timing and intensity of bird migration. Journal of Applied Ecology.* https://doi.org/10.1111/1365-2664.14342

Ware, L., Mahon, C. L., McLeod, L., & Jetté, J. F. (2023). *Artificial intelligence (BirdNET) supplements manual methods to maximize bird species richness from acoustic data sets generated from regional monitoring. Canadian Journal of Zoology, 101*(12), 1031–1051. https://doi.org/10.1139/cjz-2023-0044

Publications

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Institution where research was carried out

Postgraduate Institute of Science
University of Peradeniya
Sri Lanka

COMPARATIVE EVALUATION OF MACHINE LEARNING ALGORITHMS FOR SEX IDENTIFICATION FROM FEMUR FRAGMENTS IN SRI LANKAN POPULATION

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Sex identification is one of the most critical steps in developing a biological profile for unidentified skeletal remains. Traditionally, the pelvis and skull are used due to their high dimorphic properties; however, these bones are often unavailable in forensic contexts due to fragmentation or environmental degradation. In such scenarios, the femur becomes an invaluable alternative due to its size, density, and relative preservation in decomposed or archaeological remains. This research investigates the effectiveness of various machine learning (ML) techniques in determining sex using osteometric measurements from fragmented femora of Sri Lankan origin. The study sought to determine whether automated classifiers could provide better accuracy and robustness than statistical models such as Discriminant Function Analysis (DFA) and Logistic Regression (LR), which often assume linear separability and can suffer from bias due to small or imbalanced datasets.

Methodology

The primary objectives of the research were threefold: to explore whether ML algorithms can accurately classify sex from femoral measurements, to evaluate and compare the performance of multiple classification techniques, and to enhance prediction accuracy through systematic hyperparameter tuning and cross-validation. The dataset comprised 86 adult femora (60 male and 26 female) collected from the bone archive of the Faculty of Dental Sciences, University of Peradeniya. Eleven measurements were taken using an osteometric board and sliding caliper, capturing key dimensions such as femur length, mid-shaft diameters, and bicondylar breadth. To ensure consistency and comparability, all data underwent preprocessing including Min-Max scaling and standardization. The cleaned data was then split using two strategies: an 80/20 and a 70/30 train-test division, respectively. To address the class imbalance and reduce overfitting,

stratified k-fold cross-validation with k=10 was used across all experiments.

Sixteen widely used machine learning classifiers were tested in this study to evaluate their effectiveness in classifying sex based on femoral measurements. These included linear models such as Logistic Regression (LR) and Linear Discriminant Analysis (LDA); a distance-based model, K-Nearest Neighbors (KNN); tree-based models including Decision Tree (DT), Random Forest (RF), and Extra Trees (ETREE); and boosting algorithms like AdaBoost (ADA), Gradient Boosting (GB), and XGBoost (XGB). The study also examined a neural network model, Multi-Layer Perceptron (MLP); an optimization-based model, Stochastic Gradient Descent (SGD); a lightweight boosting method, LightGBM (LGBM); and an ensemble method, Bagging Classifier (BAGG). Probabilistic classification was tested using Gaussian Naive Bayes (GNB), while kernel-based models included Support Vector Classifier (SVC) and Gaussian Process Classifier (GPC). These classifiers were chosen to represent a broad spectrum of algorithmic strategies, from simple linear and probabilistic models to complex tree-based ensembles and kernel-based methods. To improve predictive performance and mitigate issues related to the small and imbalanced dataset, hyperparameter tuning was conducted using Grid Search, along with 10-fold stratified cross-validation to ensure balanced model training and evaluation. Metrics derived from the confusion matrix, such as accuracy, precision, recall, specificity, and F1-score, were used to compare model performance before and after tuning.

Results and Discussion

The cross-validation results for test set sizes of 20% and 30% using stratified 10-fold cross-validation indicated that Extra Trees (ETREE) achieved the highest mean accuracy of 91% for the 20% test size. For the 30% test size, both Multi-Layer Perceptron (MLP) and ETREE achieved the highest mean accuracy of 87%, highlighting ETREE's consistently strong performance across varying test scenarios (Figure 1).

This study evaluated multiple machine learning models for sex determination from skeletal remains using performance metrics such as F1-score, precision, recall, specificity, and accuracy, across two test splits (20% and 30%), before and after hyperparameter optimization via Grid Search Tuning (GST) (Table 1). Among the tested algorithms, K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Extra Trees (ETREE), AdaBoost (ADA), and Gaussian Process Classifier (GPC) showed the strongest overall performance. Specifically, KNN achieved the highest accuracy (94.1%) and F1-score (95.7%) at the 20% test size, while SVM performed best at the 30% test size with an accuracy of 96.2% and an F1-score of 97.3%. ETREE, ADA, and GPC consistently demonstrated strong results across metrics, notably achieving perfect precision and specificity. The application of GST generally enhanced model performance, emphasizing the critical role of hyperparameter tuning and appropriate test size selection in improving model accuracy for sex determination using skeletal remains.

Sex determination is crucial in forensic identification, especially when skeletal remains are fragmented. Traditional statistical methods based on regression have typically been employed, but they may fail to capture complex, nonlinear relationships among osteometric measurements. In contrast, this study emphasizes the advantages of machine learning (ML) algorithms, highlighting models such as KNN, SVM, ETREE, ADA, and GPC. ETREE and MLP consistently delivered high accuracy across stratified cross-validation (91% accuracy for a 20% test size, 87% for a 30% test size), and KNN exhibited superior performance, notably in F1-score and accuracy. SVM resulted excellent recall rates, reaching perfect scores under certain conditions. Hyperparameter optimization using Grid Search Tuning (GST) significantly improved some models, while others showed minimal enhancement, underscoring the importance of careful configuration. Comparatively, previous studies using traditional and ML approaches reported varying accuracies, typically ranging from 70% to 97%. By employing advanced ML algorithms combined

with optimized hyperparameters and suitable test splits, this study effectively demonstrates the potential of ML to surpass traditional methods in forensic sex determination, particularly within the Sri Lankan population context.

Conclusion

This study demonstrates the strong potential of machine learning algorithms for sex estimation from femoral fragments, confirming the femur's reliability as a key skeletal element in forensic identification. Among the evaluated models, KNN, SVM, and ETREE consistently achieved superior performance across key metrics such as accuracy, F1-score, precision, recall, and specificity, with RF, GPC, and ADA also showing notable classification strength. Stratified k-fold cross-validation confirmed the robustness of these models, and independent test set results reinforced their reliability. While Grid Search Tuning (GST) enhanced performance for certain models, its benefits were model-dependent, highlighting the need for tailored hyperparameter optimization. The findings align with existing forensic anthropology research, supporting the integration of advanced ML approaches with traditional osteometric methods to improve predictive accuracy. However, to ensure broader applicability, future work should validate these models on larger and more diverse population datasets to address variability in skeletal morphology across different groups.

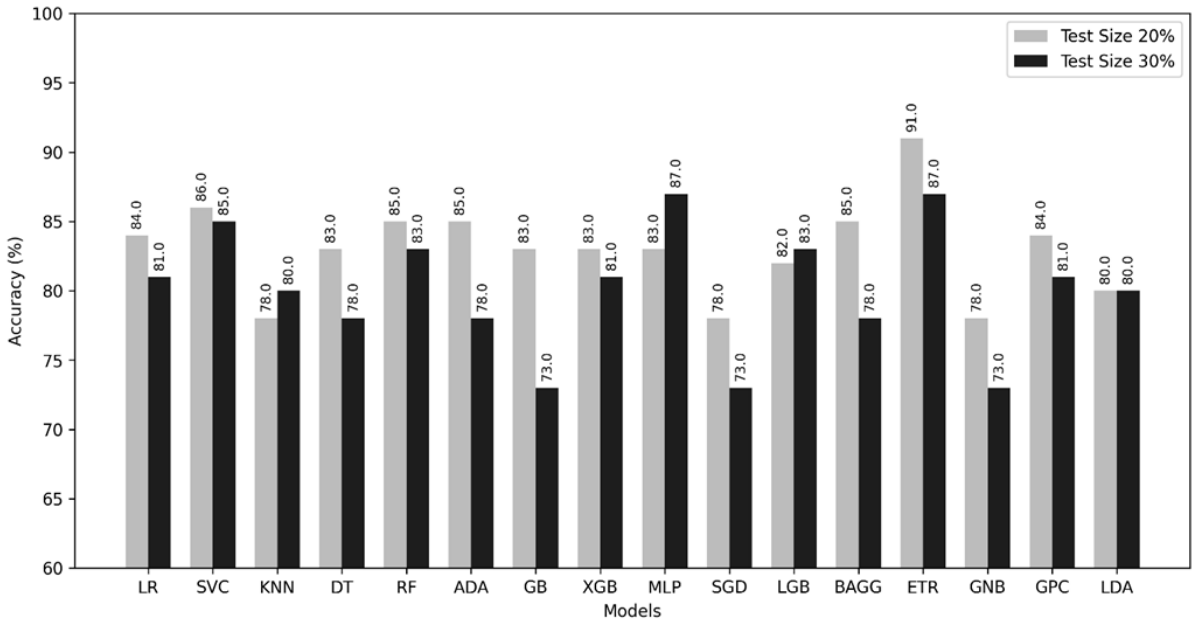

Figure 1. Results for test sizes of 20% and 30% of stratified 10-fold cross-validation.

Table 1. Comparative Evaluation of Machine Learning Models Using Five Metrics: F1 Score, Precision, Recall, Specificity, And Accuracy, Across Default And Grid Search Tuned (GST) Settings For Both 20% And 30% Test Splits.

Model	F1				Precision				Recall				Specificity				Accuracy			
	20%	GST 20%	30%	GST 30%	20%	GST 20%	30%	GST 30%	20%	GST 20%	30%	GST 30%	20%	GST 20%	30%	GST 30%	20%	GST 20%	30%	GST 30%
LR	91.7	81.8	94.4	87.5	91.7	90.0	94.4	100.0	91.7	75.0	94.4	77.8	80.0	80.0	87.5	100.0	88.2	76.5	92.3	84.6
SVM	91.7	91.7	97.3	90.0	91.7	91.7	94.7	81.8	91.7	91.7	100.0	100.0	80.0	80.0	87.5	50.0	88.2	88.2	96.2	84.6
KNN	95.7	95.7	90.9	83.9	100.0	100.0	100.0	100.0	91.7	91.7	83.3	72.2	100.0	100.0	100.0	100.0	94.1	94.1	88.5	80.8
DT	90.9	90.9	88.2	83.9	100.0	100.0	93.8	100.0	83.3	83.3	83.3	72.2	100.0	100.0	87.5	100.0	88.2	88.2	84.6	80.8
RF	90.9	87.0	94.1	91.4	100.0	90.9	100.0	94.1	83.3	83.3	88.9	88.9	100.0	80.0	100.0	87.5	88.2	82.4	92.3	88.5
ADA	85.7	85.7	87.5	94.1	100.0	100.0	100.0	100.0	75.0	75.0	77.8	88.9	100.0	100.0	100.0	100.0	82.4	82.4	84.6	92.3
GB	90.9	90.9	90.9	87.2	100.0	100.0	100.0	81.0	83.3	83.3	83.3	94.4	100.0	100.0	100.0	50.0	88.2	88.2	88.5	80.8
XGB	85.7	90.9	90.9	88.2	100.0	100.0	100.0	93.8	75.0	83.3	83.3	83.3	100.0	100.0	100.0	87.5	82.4	88.2	88.5	84.6
MLP	87.0	83.3	94.4	86.5	90.9	83.3	94.4	84.2	83.3	83.3	94.4	88.9	80.0	60.0	87.5	62.5	82.4	76.5	92.3	80.8
SGD	87.0	87.0	87.5	91.4	90.9	90.9	100.0	94.1	83.3	83.3	77.8	88.9	80.0	80.0	100.0	87.5	82.4	82.4	84.6	88.5
LGBM	85.7	85.7	88.2	90.9	100.0	100.0	93.8	100.0	75.0	75.0	83.3	83.3	100.0	100.0	87.5	100.0	82.4	82.4	84.6	88.5
BAGG	91.7	90.9	91.4	87.5	91.7	100.0	94.1	100.0	91.7	83.3	88.9	77.8	80.0	100.0	87.5	100.0	88.2	88.2	88.5	84.6
ETREE	90.9	90.9	94.1	94.4	100.0	100.0	100.0	94.4	83.3	83.3	88.9	94.4	100.0	100.0	100.0	87.5	88.2	88.2	92.3	92.3
GNB	87.0	87.0	91.4	91.4	90.9	90.9	94.1	94.1	83.3	83.3	88.9	88.9	80.0	80.0	87.5	87.5	82.4	82.4	88.5	88.5
GCP	91.7	87.0	94.4	94.4	91.7	90.9	94.4	94.4	91.7	83.3	94.4	94.4	80.0	80.0	87.5	87.5	88.2	82.4	92.3	92.3
LDA	85.7	85.7	90.9	90.9	100.0	100.0	100.0	100.0	75.0	75.0	83.3	83.3	100.0	100.0	100.0	100.0	82.4	82.4	88.5	88.5

Selected References

Du Jardin, Ph., Ponsaillé, J., Alunni-Perret, V., Quatrehomme, G. (2009). A comparison between neural network and other metric methods to determine sex from the upper femur in a modern French population. Forensic Science International 192(1): 127.e1–127.e6.

Nanayakkara, D., Vadysinghe, A., Nawarathna, L.S. (2020). Prediction of the length of the femur from its fragments in a Sri Lankan population. Australian Journal of Forensic Sciences 52(3): 303–312.

Nasien, D., Ali, N.A., Rahayu, Y. (2021). Determination of sex and race in forensic anthropology: A comparison of artificial neural network and support vector machine. Proceedings of the International Conference on Computational Intelligence and Engineering (IC2IE).

Ranaweera, L., Cabral, E., Dissanayaka, P., Lakshan, W.S.V. (2022). Estimation of sex from the osteometric measurements of the femur in a contemporary Sri Lankan population. International Journal of Morphology 40.

Publications And Patents (Under Review)

Rushda, M. U. F., Nawarathna, L. S., Yapa, R. D., & Arambawatta, A. K. S. (2025). *Comparison of machine learning classification techniques for sex determination using the length of the femur fragments. Journal of the National Science Foundation of Sri Lanka.*

Thesis reference

Rushda, MUF. (2024). Comparison of Machine Learning Classification Techniques for Sex Determination Using the Length of Femur Fragments. M.Sc. Thesis, Postgraduate Institute of Science (PGIS), University of Peradeniya, Sri Lanka.

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DATA-DRIVEN PRODUCTION MANAGEMENT WITH PREDICTIVE MODELS IN THE GARMENT INDUSTRY

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The garment manufacturing industry is one of the oldest manufacturing industries of human civilization which heavily uses manpower as well as machinery. Currently, the evolution of industry has expanded from small tailor shops to massive businesses across the world. Unlike other industries, garment manufacturing is highly prone to change its processes and manufacturing environments frequently to stand out in the apparel industry due to frequent changes in styles, lack of labor, competition with co-industries, growth of technology, etc. After years of experience, for the apparel industry, there are certain KPIs that are globally identified to help gauge their businesses towards attaining key business objectives or targets. Some of them are 'Factory Efficiency Percentage', 'Man-to-Machine Ratio', 'Cut to ship ratio', 'Order to ship ratio', 'On-Time Delivery Rate', 'Average style change over time', 'Right First Time (RFT) quality', 'Quality of production' and 'Downtime percentage'.

Sri Lanka is one of the leading exporters of apparel in the world and is considered one of the most sustainable apparel partners in South Asia. Throughout past decades there were and there have been numerous Sri Lankan apparel manufacturers who have gained a strong reputation on manufacturing globally recognized iconic brands. Even in recent years, the apparel industry has been the largest contributor to the Sri Lankan economy as it is one of the largest foreign currency gainers and the largest employer of the country. According to the statistics of revenue growth of the country for recent years by the Export Development Board, it shows a growth year by year. However, it is necessary to be cautious and explore on market needs and potential dangers to sustain and continue growth in the global market.

At present, Sri Lanka is already facing difficulties due to the energy crisis in Europe and the United States of America (USA). Also, within the country, uncertain power failures, increased cost in transportation, raw materials, and labor already

are challenging to the industry. Yet, there are positive outcomes due to the financial crisis in the industry; it suffers due to delays in on-time delivery, delays in raw materials, discrepancies in Return on Investment (ROI), etc. These dual crises have a great influence not only on small and medium factories, thus large-scale factories have drawn their attention to strategic plans to survive. When trying to apply strategic plans, the factories should have a good idea on where they are standing and heading, for which KPIs play a big role.

This research proposes a comprehensive system for a company in the garment industry of Sri Lanka, which has been a leading manufacturer of high-quality apparel in Sri Lanka since 1990. The company operates several large-scale production facilities with a workforce of over 3000 employees and an annual production capacity exceeding 10 million garments. Offering a range of innovative and customized clothing solutions to suit all apparel needs, the company aims to overcome the challenges in production tracking to achieve accurate KPI predictions. Despite having an established Enterprise Resource Planning (ERP) system and other supportive systems, they are not fully effective in providing real-time production status and KPIs. In the dynamic environment of garment manufacturing, tracking key performance indicators (KPIs) alone is not sufficient; anticipating future outcomes has become equally critical for maintaining competitive advantage. Predictive modeling offers a proactive approach to decision-making by leveraging historical production data to forecast essential KPIs. ML .net, a machine learning framework developed by Microsoft for .NET developers, provides a powerful platform to build and integrate these predictive capabilities into enterprise applications. With its user-friendly interface and support for a variety of regression and classification algorithms, ML .net enables non-data scientists to train, evaluate, and deploy custom machine learning models. By utilizing ML .net, this study mainly explores how predictive models can be used to enhance production efficiency, detect issues early, and support strategic planning within the garment industry.

Methodology

The physical project scope starts from the identification of raw materials to the sewing process and, once the production is done, the identification of finished goods from the sewing process which are taken to quality checking. As the main raw material to the sewing process will be “cut bundles” generated from the cutting department are considered as the input data to the system. To identify each bundle separately, a bundle tag will be used. This same bundle tag will be used to identify which raw materials are transformed to finished garments. Bundle tags are introduced and designed to print in A4 sheets using standard printers and are attached during the Cutting, to streamline the tracking process and eliminate the need for costly stickers. This work implements a mechanism to track missing and excess garments, providing comprehensive reports on production status and KPIs. Following successful implementation, the system leverages machine learning models trained on historical production data to predict and optimize KPIs to predictive analytics using Microsoft ML .net. Those KPIs include daily output for Factory Efficiency Percentage, Lost Time, and Reject Rate.

As for the initial prediction module, data from the daily KPI data report is used as the population. Due to the inadequacy of data, the data of 3 years manually collected data was also used. Those data and data were directly downloaded from the system comma-separated files and saved 60% of data as a train data set and 40% of data as a test data set. The selection of parameters, order, and removal of null values are organized in the comma-separated files. Even though AutoML/ ML .net Model Builder can be used for both feature selection and model selection, get the expertise of the target company input when selecting features, since the designed project is implemented in a company.

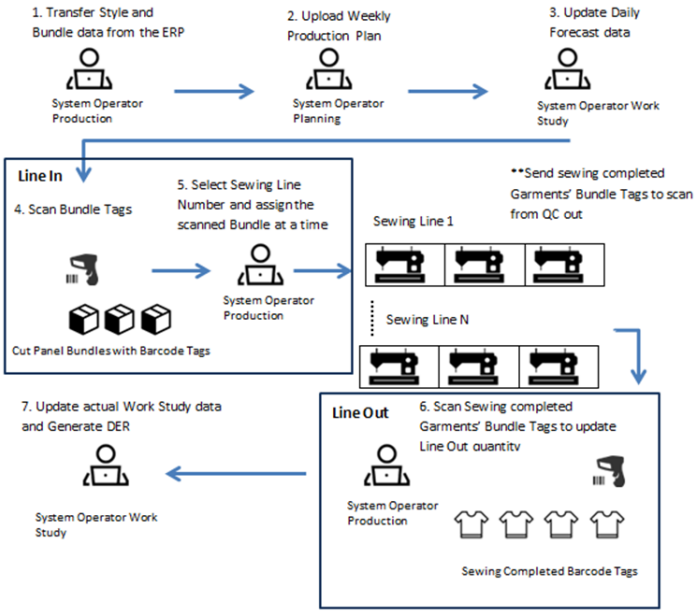

Figure 1. Data Gathering System Design

For the Actual QC Out, Lost Time, and Reject Rates prediction modules, the prediction provides regression. Mainly "Fast Tree" and "Fast Forest" are used to train the models, and the following parameters are considered.

Actual QC Out -Location, Buyer, SMV, Present MOs, Running Machines, Working Hours, Product Family, Total Lost Hours, Month Average Overall Efficiency Per Line Wise, Month Average On standard Efficiency Per Line Wise, No of Style Changes for Month.

Lost Time consists of many categories. Considered to predict lost time that category-wise mainly for quality issues. Features used - Location, Buyer, SMV, Present MOs, Running Machines, Working Hours, Product Family, Total Lost Hours, Month Average Overall Efficiency Per Line Wise, Month Average On Standard Efficiency Per Line Wise, No of Style Changes for Month and Actual QC Out.

For the Reject Percentage considered Location, Buyer, SMV, Present MOs, Running Machines, Working Hours, Product Family, Total Lost Hours, Days for Style, No of Style Changes for Month and Actual QC Out.

In the evaluation, the R-squared score and Root Mean Squared Error (RMSE) are used. Additionally, to get more idea on predictions, Mean Absolute Error (MAE), Mean Squared Error (MSE), the loss Function are calculated. Yet the author got company expertise on feature and model selection for predictions, checked for most suitable model and feature selection using Model Builder in ML .net to check the possibility to finetune models.

Results and Discussion

During initial predictions, the model for Actual QC Output produced highly deviated results. However, after applying the ML .net Model Builder's recommended model and feature set, the results significantly improved, achieving R^2 scores of 0.9797 and 0.9117, indicating excellent model fit.

In contrast, the models for predicting Lost Time and Reject Rates continued to yield suboptimal performance. Lost Time predictions, even with

Table 1. Initial Output of the prediction models

Metric	Actual Day QC Out	Lost Time (Maintenance Delays)	Lost Time (Quality Issues)	Product Recommendation (Reject Rates)	Reject %
Model Used	Fast Tree	Fast Tree	Fast Tree	Matrix Factorization	Fast Forest
R-Squared Score	0.883	-0.006	0.001	0.00019	-0.054
Root Mean Squared Error (RMSE)	237.669	38.355	6.065	4.033	4.219
Mean Absolute Error (MAE)	153.46	3.333	1.162	2.005	2.585
Mean Squared Error (MSE)	56486.38	1471.121	36.79	16.268	17.8
Loss Function	56486.38	1471.121	36.79	16.268	17.8

Table 2. Output of the prediction models for different feature selections in ML .net Model Builder

Prediction Target	Recommended Model	R^2 Score	Feature Selection
Lost Time Category B	LightGbmRegression	0.2698	9
Lost Time Category B	FastTreeRegression	0.2549	10
Lost Time Category B	FastTreeRegression	0.2739	8
Reject Percentage	FastTreeTweedieRegression	0.6027	14
Reject Percentage	FastTreeTweedieRegression	0.5516	11
Reject Percentage	FastForestRegression	-2.6039	11
Actual QC Output	FastTreeRegression	0.9797	12
Actual QC Output	FastTreeRegression	0.9117	10

different models such as LightGbmRegression and FastTreeRegression which are based on the Gradient Boosted Decision Trees algorithm, maintained low R^2 scores around 0.25–0.27. For Reject Rate prediction, FastTreeTweedieRegression which is also based on the Gradient Boosted Decision Trees algorithm produced moderately acceptable results (R^2 = 0.6027 and 0.5516), while FastForestRegression yielded a highly negative R^2 (−2.6039), signifying model failure.

Conclusion

The high-performing QC Output model can be confidently used in practice, whereas the underperforming Lost Time and Reject Rate models highlight areas for improvement, such as feature engineering or data enrichment.

These variations in model performance highlight the inherent challenges in modeling complex manufacturing KPIs, which may stem from data inadequacy, suboptimal feature selection, or the non-linear, high-variance nature of the underlying processes. Nevertheless, the use of predictive modeling remains valuable. Even where models deviate significantly, they may signal the presence of underlying process anomalies or unseen operational issues, thereby serving as an early-warning mechanism for deeper investigation and data-driven strategic planning.

Selected References

Kiron, M. (2022, June 30). KPI (key performance indicator) in garment industry. *Textile Learner.* https://textilelearner.net/kpi-key-performance-indicator-in-garment-industry/

Sarkar, P. (2022, December 19). KPIs for garment manufacturers (key performance matrices). *Online Clothing Study.* https://www.onlineclothingstudy.com/2012/05/kpis-for-garment-manufacturers.html

Sri Lanka Export Development Board. (n.d.). *Apparel & textiles suppliers, manufacturers and exporters in Sri Lanka.* https://www.srilankabusiness.com/apparel/

Rammandala, C. (2022, August 24). A close examination of Sri Lankan apparel industry. *Online Clothing Study*. https://www.onlineclothingstudy.com/2022/08/sri-lankan-apparel-industry.html

Thesis reference

Samaradiwakara, S.R.M.A.M. (2024). Data-driven production management with predictive models in the garment industry. M.Sc. Thesis, Postgraduate Institute of Science (PGIS), University of Peradeniya, Sri Lanka.

DEEP GENERATIVE ADVERSARIAL NETWORK METHOD FOR IMPROVING THE READABILITY OF EPIGRAPHY

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A key source of ancient history is the discipline of epigraphy, which provides direct evidence of the attitudes, thoughts, and cultural history of ancient civilizations. The study of "inscriptions" written on a persistent surface, such as stone, ceramic, clay, metal by an individual or group in the past, can be identified as epigraphy.

In Sri Lanka, with over the 2500 years of rich history, researchers have found significant, number of inscriptions written mainly on stone surfaces. Archeologists research on these writing to understand and discover hidden information about the history. As most of these inscriptions had been written more than thousands of years ago and were being exposed to nature for centuries, the characters on most of them have become difficult to recognize. A closer inspection exhibits that, the main reason for this illegibility is some sections of the characters or portions of the inscriptions been eroded extensively. In certain instances, this makes the entire inscription harder to read and understand.

Epigraphers relay on their understanding of the language, the character setting and the message conveyed by the inscription to recover the missing characters. With the advancement of imaging technology, researchers have attempted to use image processing and computer vision to restore the eroded characters. While there are several computer vision-based filtering algorithms available for basic image processing tasks, such as denoising, colour enhancement, and resolution improvement, these techniques fall short in recovering missing features from these images.

Traditional image recovery methods struggle to restore unrecognizable characters that have been lost due to erosion as they are unable to model the image degradation function of the natural erosion. Closer inspection of many of these eroded inscriptions shows that certain sections or characters are extensively eroded than others. This differential erosion complicates the process

of reading and understanding the inscriptions. In recent studies, learning-based image enhancement techniques have shown promising results for many problems in image processing such as image denoising, analysis and enhancement. Also, these learning-based techniques have gained immense popularity in recent years due to their ability to automatically learn from large datasets and adapt to complex patterns in images.

Moreover, they have the potential to model nonlinear behaviors, such as the differential erosion present in the eroded inscriptions.

Methodology

With this background, this study proposes a learning-based technique for recovering eroded characters, thereby enhancing the readability of these ancient inscriptions. The solution proposed in this research, models the inverse of the image degradation function using deep learning algorithm. By treating the erosion as noise, the proposed learning-based image recovery model seeks to improve the accuracy and readability of characters that have been damaged over time.

Results and Discussion

Driven by the current research interest in generative AI models, this study evaluates the suitability of a UNet-based Generative Adversarial Network (GAN) architecture for a particular application.

Conclusion

The findings confirm that a GAN-based architecture could help eliminate the bottlenecks associated with erosion in epigraphy.

Acknowledgment

The authors wish to acknowledge Professor A. Manathunga, former Director General of the Department of Archaeology in Sri Lanka, for granting permission to capture photographs of stamp images of ancient inscriptions. We extend our thanks to Mr. A. Athukorala's team from the Department of Archaeology for providing all the necessary assistance at the data collection stage of this research. Also, we would like to express our gratitude to Mr. A. Jayawardena and Mr. D. Weerakoon for their valuable support throughout this study.

Selected References

Assael, Y., Sommerschield, T., & Prag, J. (2019). Restoring ancient text using deep learning: A case study on Greek epigraphy. In *Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP)* (pp. 6368–6375). Association for Computational Linguistics. https://doi.org/10.18653/v1/D19-1678

Mikolov, T., Karafait, M., Burget, L., Cernocky, J., & Khudanpur, S. (2010). Recurrent neural network-based language model. *Interspeech*, 2(3), 1045–1048.

Sutskever, I., Martens, J., & Hinton, G. (2011). Generating text with recurrent neural networks. In *Proceedings of the International Conference on Machine Learning (ICML)* (pp. 1017–1024).

Tran, L. D., Nguyen, S. M., & Arai, M. (2020). GAN-based noise model for denoising real images. In *Proceedings of the Asian Conference on Computer Vision.*

Thesis reference

Premalal U. A. D. I., (2024) Deep Generative Adversarial Network Method for Improving the Readability of Epigrapy. MSc Thesis, Postgraduate Institute of Science, University of Peradeniya.

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NOVEL STATISTICAL MODELS FOR ASYMMETRIC HEAVY-TAILED DISTRIBUTIONS OF METHOD COMPARISON DATA

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Evaluation of two methods for measuring a continuous response variable receives considerable attention in health sciences, including biomedical engineering, clinical research, and medical imaging. These methods may involve an assay, medical device, clinical observer, measurement technique, etc., and the variables of interest may include blood pressure, heart rate, cholesterol levels, chemical concentrations, and more. Typically, new methods are compared with established methods to assess whether sufficient agreement exists between them.

With ongoing advancements in the field of medical sciences, new measurement methods and techniques are available that may be cheaper, faster, easier to use, and less invasive. However, before using such methods, it is essential to evaluate their accuracy and precision. Thus, detailed research in this area is vital for enabling health professionals to choose the most appropriate and effective measurement tools and treatment strategies.

Conventionally, standard mixed-effects models are used for analyzing method comparison data, assuming normality for both random effects and error terms. However, these assumptions are frequently violated in real-world scenarios due to skewness and heavy-tailed distributions. Measurement errors (MEs) commonly occur in both covariate and response observations during data collection. These errors may arise from the use of different measuring scales, tools, techniques, or even human error. If such MEs are not properly accounted for, the resulting conclusions can be misleading. To illustrate, consider the gold particle dataset, where two different methods were used to measure particle size: Classical Method (standard method) and Screen Fire Assay Method (new method), both in mmHg. The histograms below display the distribution of measurements for each method.

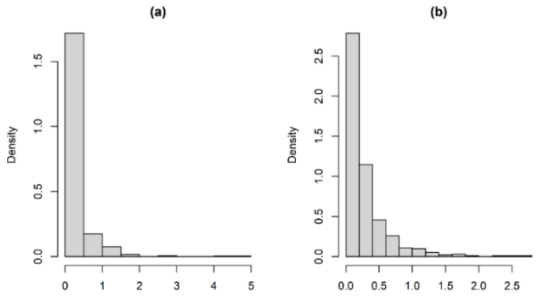

Figure 1. Histogram of the gold particle data taken by two measurement methods: (a) Classical method (b) Screen Fire Assay method.

As seen above, both measurements are right-skewed, and the data include outliers. These distributional characteristics violate the assumption of normality and highlight the limitations of conventional models. To address these challenges, this study proposes a framework for modeling method comparison data for quantitative measurements with MEs, called the Measurement Error Model (MEM). While existing MEMs typically assume normality for the true covariates and errors, this study introduces four major contributions within the MEM framework, especially to accommodate asymmetric and heavy-tailed distributions. First, the Skew-t centred Student's t MEM (STcT-MEM) is proposed for unreplicated data between two methods, where the true covariate follows a skew-t (ST) distribution (Azzalini and Capitanio, 2003) and the error terms follow a centred Student's t (cT) distribution (Sutradhar, 1993). This model captures both skewness and varying degrees of tail heaviness in the data. Second, for replicated data, the Skew-t Replicated MEM (ST-RMEM) is developed, assuming a ST distribution for the true covariate and a t distribution for the error terms. The study further generalizes this framework through the generalized Scale Mixtures of Skew-Normal Replicated MEM (GSMSN-RMEM), which allows different levels of tail heaviness in the true covariate and errors using distributions from the scale mixtures of skew-normal (SMSN) family—such as the ST, skew-generalized t (SGT) (Ferreira et al., 2011), and skew-slash (SS) (Wang and Genton, 2006) distributions. This model provides greater flexibility for handling a wide range of non-normal data structures. The approach is also extended to accommodate more than two measurement methods.

The above objectives are supported by the following specific aims:

- Develop an expectation maximization (EM) or expectation conditional maximization (ECM) algorithm for fitting the proposed models.
- Derive expressions for some common measures of agreement within the proposed models.
- Examine properties of estimators of parameters in the proposed models and compare them with some existing models via a simulation study.
- Analyze a real method comparison data set to illustrate our methodology.

Methodology

Method comparison data are commonly analyzed using standard mixed-effects models, which assume normality for both random effects and error terms. However, these assumptions are frequently violated in practice due to the presence of skewness and heavy tails in the data. To address these limitations, we propose several advanced models within the MEM framework.

First, we develop the STcT-MEM for unreplicated method comparison data. The model is specified as:

$$\boldsymbol{Y_i} = \boldsymbol{A} + \boldsymbol{B}b_i + \boldsymbol{\psi_i}, \quad i = 1, \dots, m \qquad (1)$$

where,

$$\boldsymbol{Y_i} = (Y_{i1}, Y_{i2})^T, \boldsymbol{A} = (0, \alpha)^T, \boldsymbol{B} = (1, \beta)^T$$

$$\boldsymbol{\psi_i} = (\delta_{i1}, \mathcal{E}_{i2})^T,\ b_i \sim ST(\mu_b, \phi_b, \lambda_b, \eta_b)$$

$$\boldsymbol{\psi_i} \sim ct_2(\mathbf{0}, \boldsymbol{\Sigma_{1i}}, \eta_e)$$

with, $\boldsymbol{\Sigma_{1i}} = diag(\phi_{\delta_i}, \phi_{\mathcal{E}_i})$assumed to be known. Here, μ_b is a location vector, ϕ_b is a positive definite scale matrix, λ_b is a vector of skewness parameters, and η_b band η_e are the degrees of freedom controlling the tail heaviness of the distributions of b_i and $\boldsymbol{\psi_i}$, respectively. The terms

δ_{i1} and $\mathcal{E}_{i2}$ represent the measurement errors associated with methods 1 and 2.

This model assumes a ST distribution for the true covariate and a cT distribution for the error terms, allowing for different degrees of freedom for the covariate and error components. Parameter estimation is carried out using the ECM algorithm (Meng and Rubin, 1993). To assess agreement between the two methods, we compute the Total Deviation Index (TDI) and the Concordance Correlation Coefficient (CCC).

Next, we extend the model (1) to accommodate replicated method comparison data. Let $\boldsymbol{Y}_i = \left(\boldsymbol{Y}_{i1}{}^T, \boldsymbol{Y}_{i2}{}^T\right)^T, i = 1, \dots, m,$where $\boldsymbol{Y}_{ij} = \left(Y_{ij1}, Y_{ij2}, \dots, Y_{ijn_j}\right)^T$ for $j = 1,2,$ and n_1 and n_2 are the number of replicates for methods 1 and 2, respectively. The model components are defined as:

$$\boldsymbol{A} = \begin{bmatrix} \mathbf{0}_{n_1} \\ \alpha\mathbf{1}_{n_2} \end{bmatrix} \boldsymbol{B} = \begin{bmatrix} \mathbf{1}_{n_1} \\ \beta\mathbf{1}_{n_2} \end{bmatrix} \boldsymbol{\psi}_i = \begin{bmatrix} \boldsymbol{\delta}_{i1} \\ e_i\mathbf{1}_{n_2} + \boldsymbol{\mathcal{E}}_{i2} \end{bmatrix},$$

Where $\boldsymbol{\delta}_{i1} = \left(\delta_{i11}, \dots., \delta_{i1n_1}\right)^T$, $\boldsymbol{\mathcal{E}}_{i2} = \left(\mathcal{E}_{i21}, \dots., \mathcal{E}_{i2n_2}\right)^T$, and e_i is the equation error.

The distributional assumptions are: $b_i \sim ST_1(\mu_b, \phi_b, \lambda_b, \vartheta), e_i \sim t_1(0, \phi_e, \vartheta)$, $\delta_{i1k} \sim t_1(0, \phi_\delta, \vartheta)$ and $\mathcal{E}_{i2k} \sim t_1(0, \phi_\varepsilon, \vartheta)$. For comparative evaluation, we also consider the skew-normal (SN) and normal (N) distributions.

However, this replicated model assumes equal tail heaviness for the covariates and errors, which limits its flexibility. To overcome this, the model is generalized to handle varying tail heaviness in the true covariates and errors by employing SMSN distributions, including ST, SGT (Ferreira et al., 2011), and SS (Wang and Genton, 2006). This extended model is termed the GSMSN-RMEM. Finally, the GSMSN-RMEM is extended to handle multiple method comparisons, providing a flexible and robust framework capable of assessing agreement among more than two measurement methods. The proposed methodologies are numerically assessed through simulation studies in various scenarios with small, moderate, and large samples and are illustrated using real datasets.

Results and Discussion

For the STcT-MEM model, simulation results indicate that the values of bias, standard deviation (SD), and root mean square error (RMSE) decrease as the sample size and skewness parameter (λ_b) increase, as theoretically expected. The bias, SD, and RMSE of the maximum likelihood (ML) estimates based on STcT-MEM are consistently lower than those obtained from the standard normal MEM (N-MEM). Additionally, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values are smaller under the STcT-MEM model, confirming its superior fit. Application to a real gold particle dataset further demonstrates that STcT-MEM outperforms the N-MEM.

For the ST-RMEM model, simulation studies show that as the number of subjects increase from 20 to 100, the estimates become more accurate. Both relative efficiency and coverage probabilities (CPs) improve with increasing sample size. Application to subcutaneous fat data confirms the efficiency and robustness of the ST-RMEM model, particularly for data exhibiting skewness and heavy tails.

Regarding the GSMSN-RMEM, simulation studies demonstrate their superior performance under ST and SGT distributions (see Figure 2). The effectiveness of these models is further validated through systolic blood pressure measurements.

The probability of agreement is used (see Figure 3) further to assess the agreement between the two measurement methods. Similarly, the GSMSN-MRMEM shows superior performance under the same distributions in simulation studies. Its effectiveness is further confirmed using a tumour dataset.

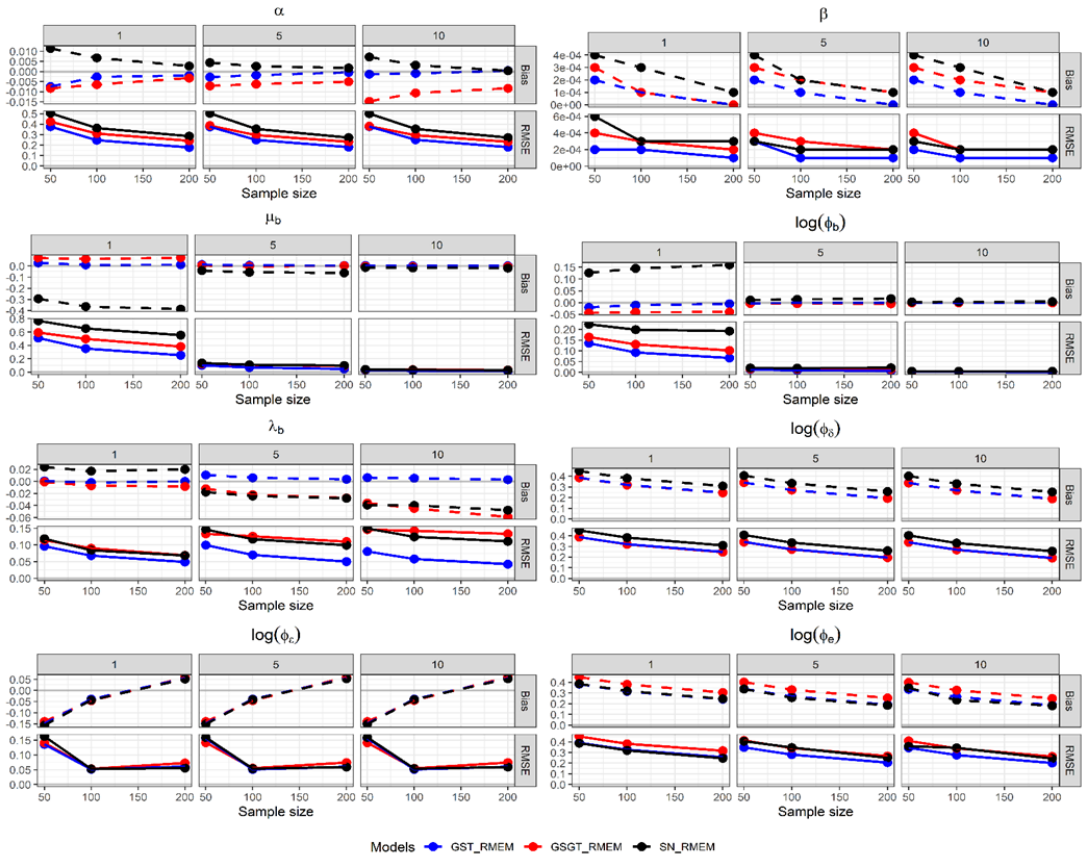

Figure 2. BIAS and RMSE values for GST-RMEM, GSGT-RMEM, and SN-RMEM based on 500 Monte Carlo samples.

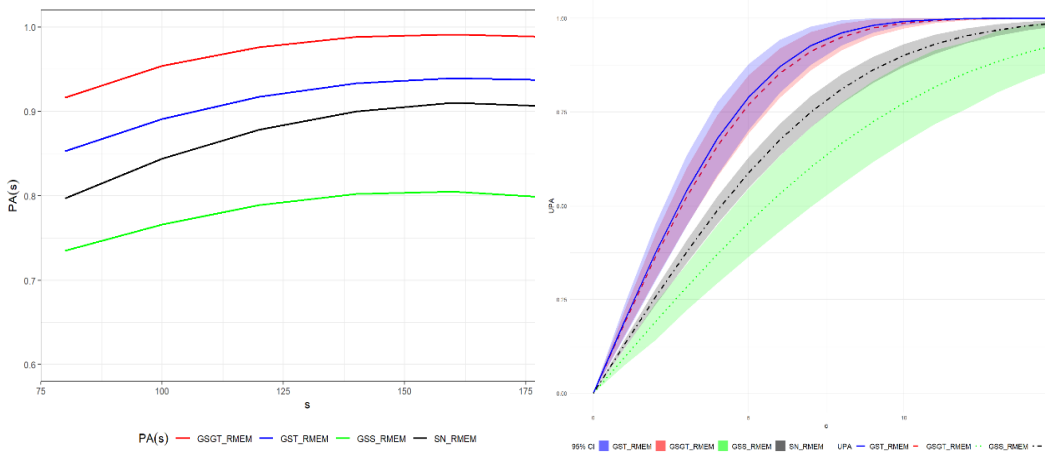

Figure 3. Probability of agreement plot (left panel) with c=10, and unconditional probability of agreement plot (right panel) against ***c***, based on systolic blood pressure data

Conclusion

This study proposes four novel models within the MEM framework to assess agreement between methods under asymmetric, heavy-tailed distributions. First, the STcT-MEM model is developed for unreplicated method comparison data, allowing different tail behaviors for the true covariate and error terms. It uses a ST distribution for the covariate and a cT for the error. Simulations and gold particle data confirm its superiority over the standard N-MEM, particularly under non-normal conditions with measurement errors. Second, the ST-RMEM model extends the approach to replicated data, maintaining flexibility in handling skewness and heavy tails. Results from simulations and subcutaneous fat data show accurate and reliable performance in evaluating agreement. Third, the GSMSN-RMEM model generalizes the framework using scale mixtures of skew-normal distributions, including ST, SGT, and SS, to better capture skewness, tail heaviness, and outliers. Its performance is supported by simulations and systolic blood pressure data. Lastly, the GSMSN-MRMEM model accommodates agreement assessment among multiple methods with different tail behaviors. Simulations and real tumour data confirm its superior performance under ST and SGT distributions compared to SN and N models. Together, these models provide a flexible and robust framework for analyzing method comparison data, with broad applications in biomedical engineering, clinical research, and medical imaging.

Selected References

Azzalini, A., & Capitanio, A. (2003). Distributions generated by perturbation of symmetry with emphasis on a multivariate skew t-distribution. *Journal of the Royal Statistical Society: Series B (Statistical Methodology), 65*(2), 367–389. https://doi.org/10.1111/1467-9868.00374

Ferreira, C. S., Bolfarine, H., & Lachos, V. H. (2011). Skew scale mixtures of normal distributions: Properties and estimation. *Statistical Methodology, 8*(2), 154–171. https://doi.org/10.1016/j.stamet.2010.10.001

Meng, X.-L., & Rubin, D. B. (1993). Maximum likelihood estimation via the ECM algorithm: A general framework. *Biometrika, 80*(2), 267–278. https://doi.org/10.1093/biomet/80.2.267

Sutradhar, B. (1993). Score test for the covariance matrix of the elliptic t-distribution. *Journal of Multivariate Analysis, 46*(1), 1–12. https://doi.org/10.1006/jmva.1993.1001

Wang, J., & Genton, M. G. (2006). The multivariate skew-slash distribution. *Journal of Statistical Planning and Inference, 136*(1), 209–220. https://doi.org/10.1016/j.jspi.2005.05.008

Publications

Duwarahan, J., & Nawarathna, L. S. (2022). *An improved measurement error model for analyzing unreplicated method comparison data under asymmetric heavy-tailed distributions. Journal of Probability and Statistics, 2022,* Article ID 3453912. https://doi.org/10.1155/2022/3453912

Duwarahan, J., & Nawarathna, L. S. (2020). *Skew t replicated measurement error model for method comparison data.* In *Proceedings of the PGIS Research Congress* (Vol. 9, p. 59).

Duwarahan, J., & Nawarathna, L. S. (2023). *Assessing agreement between two measurement systems using replicated scale mixtures of skew normal measurement error models with varying degrees of freedom.* In *Proceedings of the PGIS Research Congress* (Vol. 10, p. 29).

Duwarahan, J., & Nawarathna, L. S. (2024). *Analyzing method comparison data with skew normal measurement error models: Incorporating generalized scale mixtures and varying degrees of freedom. Communications in Statistics — Simulation and Computation,* 1–29. https://doi.org/10.1080/03610918.2024.2366984

Duwarahan, J., & Nawarathna, L. S. (2024). *A modified measurement error model for replicated method comparison data with skewness and heavy tails. Statistics and Applications, 22*(2), 146–167.

Duwarahan, J., & Nawarathna, L. S. (2024). *A multivariate measurement error model for method comparison data under skewed and heavy-tailed distributions.* In *Proceedings of the Ruhuna International Science and Technology Conference, 2024.*

Duwarahan, J., & Nawarathna, L. S. (n.d.). *Evaluating agreement across multiple methods with skew-normal replicated measurement error models.* Manuscript in preparation, *Journal of Probability and Statistics.*

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SMART SDLC: A TAILORED DEVELOPMENT LIFE CYCLE FOR AI, IOT, AND CLOUD SOLUTIONS

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Software plays an increasingly significant role in human life today. It is essential for efficient communication, transportation, information access, productivity, entertainment, smart task management, and automation, making it crucial for thriving in the digital world. Without it, navigating and excelling in various areas would be highly challenging.

Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), and Cloud technologies are significantly shaping the approaches of modern software development. AI software utilizes automation-related algorithms, machine learning (ML) models, and data analytic pipelines to mimic or simulate human intelligence. It performs tasks that typically require human intelligence, such as perception, reasoning, learning, and decision-making. Similarly, integration of cloud and IoT towards the software has become the emerging trend in the current era and they were essential for present complex process like smart monitoring and controlling of wastewater, smart traffic management, smart real-time data analysis, and to synergize a smart city. Cloud computing further enhances these capabilities by providing scalable, on-demand resources for computation, storage, and networking.

However, traditional Software Development Life Cycles (SDLCs) have limitations and raised concerns over their effectiveness in modern development environments. One of the primary drawbacks is their inflexibility, as they follow a linear and sequential process that mandates the completion of each phase before moving to the next, making it difficult to accommodate changes or evolving requirements without costly backtracking. These approaches, often found to prioritize documentation over working software, can lead to delays and productivity losses. Another significant issue with these SDLCs is their lack of agility, which renders them less suitable for fast-paced, dynamic projects, such as mobile applications, where quick development is crucial to remain competitive. This rigidity often

leads to inefficiencies and delays when adjustments are needed.

The evolution of traditional SDLC models has faced significant challenges in keeping up with the dynamic requirements of AI, IoT, and cloud-based applications. Conventional models rely on fixed requirements and linear processes, which are not well-suited for systems that continuously learn (AI), handle complex device networks (IoT), or require elastic scalability (cloud). To overcome these limitations, various SDLC adaptations have emerged, either introducing complete changes or partial improvements to better support trios-based developments. Complete modifications include the Cloud Software Life Cycle Process (CSLCP) that integrates risk-aware planning and retirement phases for cloud environments, and LSTM-based models for AI-driven requirement analysis. Similarly, hybrid models combining Agile and Waterfall have been proposed to address IoT-specific non-functional requirements (e.g., interoperability, scalability). Despite their innovations, these comprehensive models often lack robust guidelines for implementation, especially in areas such as risk management and testing.

Partial changes to SDLCs have also gained traction due to their easier adoption. These include tailored security strategies using frameworks like OWASP S-SDLC for IoT applications, and iterative V-models incorporating statistical validation for stakeholder alignment in smart environments. AI enhancements within SDLCs often focus on flexible requirement definitions and automated testing using ML models like ANN and DT, although testing automation remains a challenge. Similarly, cloud adaptations involve selection algorithms for service providers and checklist-based secure Agile models. Meanwhile, several reviews emphasize the need for sustainable, collaborative cloud development practices, robust healthcare app frameworks, and AI-driven automation. Despite promising directions, many models still lack end-to-end support for testing, integration, and security, necessitating a paradigm shift towards fully reimagined SDLC framework to meet the demands of Industry 4.0 technologies.

Given the limitations of existing models, we proposed a trios based SDLC (SMART SDLC) that includes AI, IoT, and cloud computing technologies. This innovative method focuses on flexibility, scalability, and real-time processing, making it perfect for designing intelligent software systems. The trio-based architecture assures that software can adapt to quickly changing data inputs and dynamically modify its operations in response to real-time feedback from IoT and cloud systems.

Methodology

Our SDLC model was developed through a structured, iterative process. First, a 12-step methodology was applied to analyze existing SDLC frameworks and identify gaps for AI/IoT/cloud use. An expert survey and literature review fed into a scoring scheme (Table I) that rated the relevance of candidate practices (e.g. AI-assisted analysis, cloud architectures, IoT tools). A K-Means clustering step then grouped the high-scoring activities into coherent phases. To ensure a robust validation of the model, Spearman's rank correlation was used due to its ability to assess the strength and direction of the association between ranked variables without assuming a normal distribution. Each conflict metric was rated on a scale of 1 to 5 which are based on the meetings that occurred with arguments, the meetings resolved the conflict occurred, the conflict occurred when experts interact with their clients, and the conflict occurred when experts interact with their teams.

Table 1. Selection of adaptable, suitable cluster and scoring criteria; * - The approaches not suitable for current development era have been given score > 100

SDLC Phases	**Scoring Range**	**Example (Scoring Criteria)**
Requirement	0-20	CSLCP Model requirement process: 10 Requirement elicitation of IoT-based model: > 100*
Design	21-40	High-Level Architectural design used in existing models: 35 CSLCP Model project management: > 100*
Implementation	41-60	Code assistant: 56 CSLCP Model Product development: > 100*
Testing	61-80	Support Representative: 76 CSLCP Model Quality assurance: > 100*
Deployment and Maintenance	81-100	CSLCP model configuration management process area: 85 Deployment techniques used in SDLC for AI developments: > 100*

The outcome is a five-phase "SMART SDLC" that retains the standard stages – Requirements, Design, Implementation, Testing, and Deployment & Maintenance (see Figure 1) based on the selected phases resulting from K-Means clustering. It integrates new techniques at each stage. For example, the requirements phase includes AI-based elicitation (natural language processing, learning models), while the design phase emphasizes IoT/cloud architectural patterns. The implementation and testing phases incorporate AI/IoT toolchains (code-assistants, automated testing), and the final phase focuses on cloud deployment strategies.

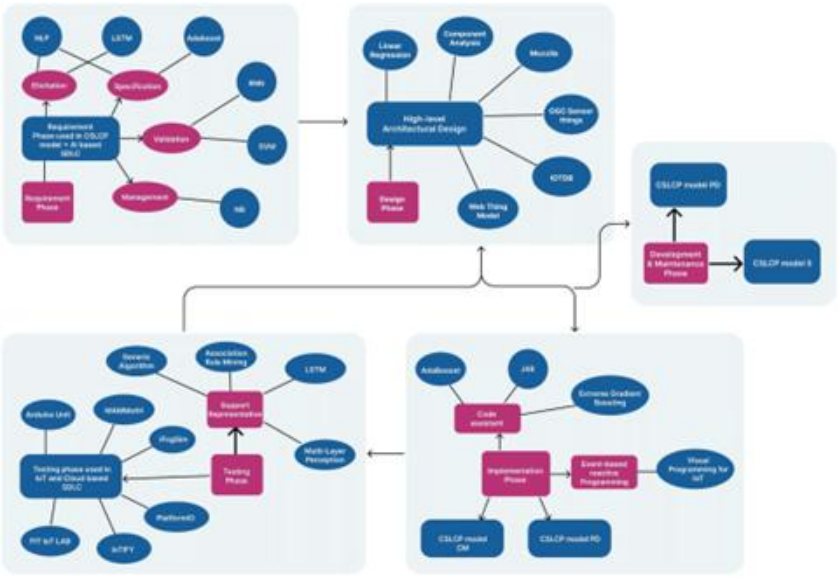

Figure 1. SMART SDLC model with added new approaches in each phase: Square – Main phases of the model; Rounded rectangle – selected approaches and sub phases used in existing trios-based development in each; Oval Techniques and tools used in such sub phases or approaches; Pink color- Existing approaches, Dark blue color- Revised approaches; Arrow- Flow of the sequence of the phases in an ordered manner; CM-Configuration Management, PD-Product Development, S- Security process used in CSLCP model.

Results and Discussion

The model has been evaluated with relevant industry experts with numerous parameters and real-world applications which is further validated with Spearman's rank correlation statistical analysis.

The resultant model has been shared among various experts. They encountered several discussions when they dealt with the clients with the help of the model. For this empirical evaluation, Spearman's rank correlation statistical analysis has been made based on the parameters like customer meeting conflicts, acceptance of each modified phase, comparison with other SDLCs and suggested improvements with an average value out of 5 and as shown in Table 2.

Table 2. Spearman's rank correlation analysis for conflict and interaction metrics in the phases of the smart SDLC

Metric Pair	Correlation (ρ)	p-value
Meetings with arguments vs. Meetings resolved conflict	0.60	0.2850
Meetings with arguments vs. Interactions client conflict	-0.30	0.6240
Meetings with arguments vs. Interactions team conflict	0.40	0.5050
Meetings resolved conflict	-0.60	0.2850

vs. Interactions client conflict		
Meetings resolved conflict vs. Interactions team conflict	0.70	0.1881
Interactions client conflict vs. Interactions team conflict	-0.90	0.0374

With this statistical analysis, it is identified that, weak negative (ρ=-0.30) and decent positive (ρ=0.40) correlations were observed between arguments and client or team conflicts, respectively; however, none of these were significant ($p > 0.5$). The most notable and significant finding was a strong negative correlation ($\rho = -0.90$, $p = 0.0374$) between client conflicts and team conflicts, highlighting that resolving client issues can significantly reduce internal team conflicts. While the correlations suggest meaningful patterns, additional data is necessary to confirm their statistical significance.

The adaptability of each phase in the SMART SDLC was analyzed based on expert feedback, with the acceptance ratios illustrated in Fig.2. Most industry professionals expressed strong acceptance of the proposed changes: 84% for the Requirement phase, 87% for the Design and Implementation phases, 89% for Testing, and 82% for Deployment and Maintenance. Conversely, 16% did not accept the Requirement phase, 13% rejected the Design and Implementation phases, 11% opposed Testing phase's alterations, and 18% disagreed with changes made in the Deployment and Maintenance phase.

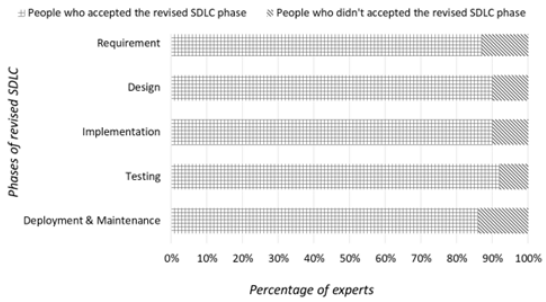

Figure 2. Acceptance rate for each phase of the SMART SDLC by various experts.

Meanwhile, experts were asked to compare the SMART SDLC model with traditional SDLC approaches such as Waterfall, Agile, Prototype, and DevOps, as shown in Figure 3. The results show that Agile and DevOps each received a decent acceptance rate, reflecting their strengths in flexibility and automation to accommodate evolving project demands. The Waterfall model, with a 17.7% acceptance rate, remains applicable for projects with strict requirements and regulatory compliance. The Prototype model, preferred by 19.3% of respondents, is favored for projects that require rapid design and validation through user feedback. Leading with a 21.7% acceptance rate, the SMART SDLC model was recognized for its adaptability, particularly due to its integration of trios-based technologies to efficiently meet modern software development needs. This distribution underscores the importance of selecting an SDLC model that aligns with project-specific requirements and highlights the dual responsibility of project managers to both choose and adapt the model as the project evolves.

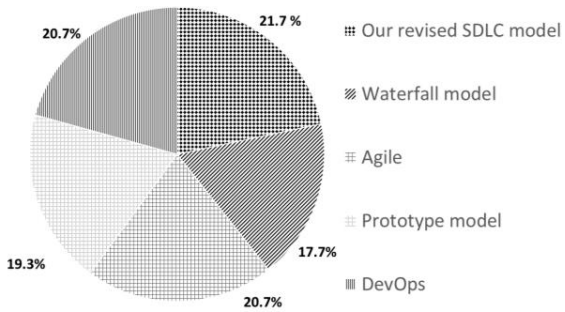

Figure 3. Comparison of SMART SDLC with exiting SDLC models. Percentages in the graph

represent the percentages of industry experts who accepted the corresponding SDLC model.

To further validate the model, its phases were compared with Google Cloud Platform's cloud-native (GCP), which is a DevOps-driven lifecycle. We found that the revised model's AI and IoT-centric paradigm, which integrates edge-simulation tools (iFogSim, PlatformIO) and ML algorithms (LSTM, J48, AdaBoost), offers modular design, real-time responsiveness, and domain-specific validation. On the other hand, GCP prioritizes elasticity, containerization, and fully managed CI/CD services (App Engine, BigQuery, Cloud Build, Cloud Monitoring. In practice, SMART SDLC enhanced Oracle NetSuite and Google Analytics 360 with intelligent decision-making and compliance enforcement. However, it still faces challenges in requirement traceability, security alignment, and real-time performance validation. Especially during the maintenance phase, the future refinements should include hybrid CI/CD pipelines, robust traceability frameworks. Similarly, the model's cloud scalability and agility should incorporate AI-driven testing reliability.

Conclusion

The SMART SDLC model enhances trios-based development by integrating specialized ML algorithms, architectural optimizations, and bespoke testing methods, addressing traditional SDLC limitations and incorporating expert feedback to refine its phases. While it outperforms Waterfall and Agile in AI-driven contexts enabling effective hardware integration and conflict management via NLP it still requires broader validation for IoT and cloud applications and greater stakeholder engagement to overcome resistance. Future work should target improvements in design, testing, and maintenance, expand expert validation globally, and explore emerging technologies such as AR/VR and mobile-cloud integration to ensure the model's adaptability and efficacy in the evolving software landscape.

Selected References

Alsari, A., Qureshi, R., & Algarni, A. (2020). Agile framework to transform traditional team. In *2020 IEEE Frontiers in Education Conference (FIE)* (pp. 1–9). IEEE. https://doi.org/10.1109/FIE44824.2020.9274240

Association for Computing Machinery. (2020). *ICSIE '20: Proceedings of the 9th International Conference on Software and Information Engineering.*

Bucchiarone, A., Cooper, K. M. L., Lin, D., Melcer, E. F., & Sung, K. (2023). Games and software engineering: Engineering fun, inspiration, and motivation. *SIGSOFT Software Engineering Notes, 48*(1), 85–89. https://doi.org/10.1145/3573074.3573096

C.P. Team. (2018, July). *CMMI for development, version 1.3.* https://doi.org/10.1184/R1/6572342.v1

Capatina, A., Kachour, M., Lichy, J., Micu, A., Micu, A.-E., & Codignola, F. (2020). Matching the future capabilities of an artificial intelligence-based software for social media marketing with potential users' expectations. *Technological Forecasting and Social Change, 151,* 119794. https://doi.org/10.1016/j.techfore.2019.119794

DeFranco, J. F., & Laplante, P. A. (2017). Review and analysis of software development team communication research. *IEEE Transactions on Professional Communication, 60*(2), 165–182. https://doi.org/10.1109/TPC.2017.2656626

de Vicente Mohino, J., Bermejo Higuera, J. R., Bermejo Higuera, J., & Sicilia Montalvo, J. A. (2019). The application of a new secure software development life cycle (S-SDLC) with Agile methodologies. *Electronics, 8*(11). https://doi.org/10.3390/electronics8111218

Fernandes, A. M., Pai, A., & Colaco, L. M. M. (2018). Secure SDLC for IoT based health monitor. In *2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA)* (pp. 1236–1241). IEEE. https://doi.org/10.1109/ICECA.2018.8474668

Gholami, M. F., Jamshidi, P., & Shams, F. (2010). A procedure for extracting software development process patterns. In *2010 Fourth UKSim European Symposium on Computer Modeling and Simulation* (pp. 75–83). IEEE. https://doi.org/10.1109/EMS.2010.24

Gorantla, V. A. K., Gude, V., Sriramulugari, S. K., Yuvaraj, N., & Yadav, P. (2024). Utilizing hybrid cloud strategies to enhance data storage and security in e-commerce applications. In *2024 2nd International Conference on Disruptive Technologies (ICDT)* (pp. 494–499). IEEE. https://doi.org/10.1109/ICDT61202.2024.10489749

Henríquez, V., Chevreux, S. E., & Henrique, G. J. (2019). Agile development of learning analytics tools in a rigid environment like a university: Benefits, challenges and strategies. In J. Scheffel, P.-S. V., I. A., & Maren Broisin (Eds.), *Transforming learning with meaningful technologies* (pp. 705–708). Springer International Publishing. https://doi.org/10.1007/978-3-030-29862-8_86

Issues in Information Systems. (2019). Agile and secure software development: An unfinished story.

Ismail, S., & Dawoud, D. W. (2022). Software development models for IoT. In *2022 IEEE 12th Annual Computing and Communication Workshop and Conference (CCWC)* (pp. 524–530). IEEE. https://doi.org/10.1109/CCWC54503.2022.9720750

Lo, D., Nagappan, N., & Zimmermann, T. (2015). How practitioners perceive the relevance of software engineering research. In *Proceedings of the 2015 10th Joint Meeting on Foundations of Software Engineering (ESEC/FSE 2015)* (pp. 415–425). Association for Computing Machinery. https://doi.org/10.1145/2786805.2786809

Mnyakin, M. (2023). Applications of AI, IoT, and cloud computing in smart transportation: A review. *Artificial Intelligence in Society, 3*(1), 9–27. https://researchberg.com/index.php/ai/article/view/108

Nag, A., et al. (2024). Exploring the applications and security threats of Internet of Things in the cloud computing paradigm: A comprehensive study on the cloud of things. *Transactions on Emerging Telecommunications Technologies, 35*(4), e4897. https://doi.org/10.1002/ett.4897

Sai Lohitha, N., & Pounambal, M. (2023). Integrated publish/subscribe and push-pull method for cloud-based IoT framework for real-time data processing. *Measurement: Sensors, 27,* 100699. https://doi.org/10.1016/j.measen.2023.100699

Salem, R. M. M., Saraya, M. S., & Ali-Eldin, A. M. T. (2022). An industrial cloud-based IoT system for real-time monitoring and controlling of wastewater. *IEEE Access, 10,* 6528–6540. https://doi.org/10.1109/ACCESS.2022.3141977

Shankar, S. P., & Chaudhari, S. S. (2023). Framework for the automation of SDLC phases using artificial intelligence and machine learning techniques. *International Journal of Recent Innovations in Trends in Computing and Communication, 11*(6s), 379–390.

Singh, A., & Kaur, P. J. (2019). Analysis of software development life cycle models. In J. K. Nath Vijay & Mandal (Eds.), *Proceedings of the Second International Conference on Microelectronics, Computing & Communication Systems (MCCS 2017)* (pp. 689–699). Springer Singapore.

Sinha, A., & Das, P. (2021). Agile methodology vs. traditional waterfall SDLC: A case study on quality assurance process in software industry. In *2021 5th International Conference on Electronics, Materials Engineering & Nano-*

Technology (IEMENTech) (pp. 1–4). IEEE. https://doi.org/10.1109/IEMENTech53263.2021.9614779

Subha, R., & Zhang, J. (2022). An optimal construction of smart aged homes based on SDLC using smart sensors and agent networks. *International Journal of Intelligent Networks, 3,* 138–142. https://doi.org/10.1016/j.ijin.2022.09.003

Publications

Vigneshwaran, P., Kartheeswaran, T., & Kodithuwakku, S. (2025). *SMART SDLC: A tailored development life cycle for AI, IoT, and cloud solutions.* Manuscript under preparation, *Turkish Journal of Electrical Engineering and Computer Sciences.*

Thesis reference

P. Vigneshwaran, (2024) Smart SDLC: a tailored development life cycle for AI, IOT, and cloud solutions, M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya, pp. 133, 2024.

A DESCRIPTIVE STUDY ON RISK FACTORS FOR AND TYPES OF CURATIVE CARE AND EARLY REHABILITATIVE CARE PROVIDED TO PATIENTS ADMITTED WITH ACUTE MYOCARDIAL INFARCTION TO THE CARDIOLOGY UNIT OF THE NATIONAL HOSPITAL KANDY

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Cardiovascular diseases (CVD) are a group of diseases coming under the category of non-communicable disease (NCD), which leads to high morbidity and mortality worldwide. Acute Myocardial Infarction (AMI) is a primary component of CVD in the world and may create a serious health problem. AMI is also known as a heart attack and occurs when blood stops flowing properly to a portion of the heart, and the heart muscle is injured because it is not receiving enough oxygen. It is the most common and most dangerous disease in developed countries and low and middle-income countries.

AMI is the most common cause of hospital admission as well as death among coronary artery diseases. Several factors related to the severity of the disease have been identified. They are smoking, diabetes mellitus, hypertension, and dyslipidemia. Furthermore, the contribution of risk factors like age, sex, obesity, family history, alcohol consumption, physical inactivity and stroke was identified.

With the development of recent science and technology, there has been considerable improvement in clinical outcomes of patients treated for AMI through percutaneous coronary intervention (PCI), coronary angiogram (CA), angioplasty, coronary artery bypass grafting (CABG) and advances in medical treatment for secondary prevention. Optimal care of myocardial infarction (MI) in the acute and subacute period focuses on improving the discharge planning process, implementing therapies early to prevent recurrent MI and avoiding hospital admissions and reducing mortality. It has improved the quality of life for patients and reduced the medical cost.

Comprehensive cardiac rehabilitation (CR) programs may improve risk factor management, reduce mortality, reduce the rate of rehospitalization, improve functional capacity

and quality of life and reduce medical cost. Cardiac rehabilitation programs considerably differ with regard to rehabilitation settings, which are inpatient, outpatient, centre-based and home-based, and it includes a multidisciplinary rehabilitation team such as cardiologists, physicians, nurses specialized, psychologists, physiotherapists, dieticians and social workers. Further education programs include information on medication, risk factor management, exercise training, nutritional advice, support to stop smoking and physiotherapy.

In Sri Lanka the government has invested heavily in AMI management, including catheterization laboratories, imaging facilities, laboratory services and pharmacology in tertiary care centers as well as immediate and intermediate centers for management of patients presenting with AMI.

This study strived to achieve several objectives. Firstly, to identify the prevalence of major risk factors, smoking, hypertension, diabetes mellitus and dyslipidemia, patients' cardiovascular history and relevant family history for Acute Myocardial Infarction among admitted patients with Acute Myocardial Infarction (AMI) in the cardiology unit in the National Hospital Kandy (NHK).

Secondly, to describe the type of curative care (pharmacological treatment, non-pharmacological treatment, invasive procedures) which receive patients admitted with Acute Myocardial Infarction in the cardiology unit of NHK. Finally, to describe the early rehabilitative care, education programs including information on medication, risk factor management, individual nutritional advice and exercise training programs for Acute Myocardial Infarction among hospitalized patients in the cardiology unit in NHK.

Methodology

All the consecutive patients (320) with AMI admitted to the coronary care unit and cardiology wards were recruited for the study during the data collection period, May 2023 to July 2023. A descriptive cross-sectional study design was used for this study, and an interviewer administered a newly created structured questionnaire. Bead head tickets (BHTs), Electrocardiography (ECG) records, Coronary angiogram, PCI reports and biochemical reports were used as data sources and entered into the data sheet. Data was collected from the questionnaires by the researcher. The collected data were entered into a Microsoft Excel worksheet, and the data were analyzed by using Statistical Package of Social Science (SPSS) software with the assistance of an experienced statistician. Ethical approval was obtained from the Ethics Review Board in the National Hospital, Kandy, prior to commencement of the study. Informed written consent was obtained from each participant.

The respondents were aged between 30-75 years, while the majority were male, 226/320 (70.6%) and the mean age of the population was 56 ± 11 years. In addition, the majority of participants were Sinhala and Buddhist, 228 (71.2%), while 19.1% were Muslim; the rest were Hindu, 9.4% and Christian, 0.3%. Most of the subjects were married 305, (95.31%), and 14.4% were single. When considering the occupational status, 30.6% were self-employed, 26.6% were unemployed, 23.8% were employed in private sector, and 10.63% and 8.4% were government employees and farmers, respectively. The majority of the AMI were patients, 231 (72.4%) were admitted to the NHK from the Kandy district and 7.8% from Matale and 8.8% from the Kegalle district. Further, NHK provided acute care for patients who were from Badulla, Monaragala, Kurunegala and Nuwara Eliya districts.

Results and Discussion

Out of 320 patients, 124 (39.62%) were current smokers, and the mean number of cigarettes per day was 4.96± 2.8, and the mean duration of smoking was 21 ± 10.5 years. 137 (43.77%) were never been smokers. Fifteen patients used illegal drugs. A little over three-quarters (24.5%) had a family history of MI. When considering the patients' past medical history, 33 (10.3%) had a prior history of MI, out of 320 participants, 113 (35.42%) had hypertension, 91 (29.84%) had Diabetes Mellitus, 78 (24.53%) had dyslipidemia and 9 (2.81%) had cerebrovascular accident. Among the 320 patients, 111(34.6%) were in the

overweight category, considering Body Mass Index (BMI) and 28 (8.7%) were obese, 171 (53.30%) were under the normal weight category.

Out of 320 participants, 124 (38.75%) consumed fried foods such as crisps, snacks, chips and nuts, 131(40.94%) regularly ate sweets, cakes, biscuits and chocolates. The majority of patients, 228 (74.38%), had not taken five portions of fruits and vegetables per day, while 7.18% subjects added salt to meals at the table as a habit. Nearly one third (35.31%) of patients skipped their main meals. However, a considerable proportion of participants drank plenty of fluid at regular intervals during the day. Considering the physical activity of the study sample, 30 (9.37%) patients' work involved vigorous intensive activities, and the mean days were 4.2 ± 1.4 and 86 (27.81%) patients' work involved moderate intensive activities, and the mean days were 4.44 ± 1.27. Nearly half of the subjects, 143 (44.68%), walked or use a pedal cycle on a typical day, and the mean time was 30.49 ±11.76 minutes.

As curative care, considering the pharmacological treatment, 312 of 320 (97.5%) patients were prescribed Aspirin, 309 (96.56%) Clopidogrel and 314 (98.13%) Statin were prescribed. Among the admitted patients with AMI, 243 (77.14%) received Low Molecular Weight Heparin (LMWH). For thrombolytic agents, 95 (29.68%) patients and 33 (10.03%) patients were facilitated with Tenecteplase and Streptokinase, respectively. Among the subjects, 62.5% and 65.41% were administered ACE inhibitors and Beta-Blockers, respectively.

In patients admitted with AMI, 113 (35.31%) underwent Coronary angiogram as a reperfusion invasive procedure. Among others, 69 (21.56%) underwent Primary Percutaneous Coronary Intervention (PPCI), and 12.81% received rescue PCI. A very few patients, 6 (1.87%), underwent Coronary Artery Bypass Grafting (CABG) for the treatment of AMI. Among those patients, 21.56% and 12.81% underwent PPCI and PCI. When considering the affected area for PCI, 23.12% the Left Anterior Descending (LAD), 8.43% Right Coronary Artery (RCA) and Left Circumflex Artery (LCX) and the Obtuse Marginal Artery (OM) were affected.

Out of 320 patients, 219 patients facilitated with Troponin test, and among them, 139 (43.43%) were Troponin positive and 25.6% were Troponin negative. When considering the other biochemical markers, 314 (98.13%) Full Blood Count (FBC), 302 (94.37%) Renal Function Test (RFT), 259 (83%) Liver Function Test (LFT) and 205 (64.06%) Fasting Blood Sugar (FBS) and 60.03% Random Blood Sugar (RBS) were investigated at the hospital stay.

All the patients were facilitated with Electrocardiography (ECG), and according to the ECG, there were ST-segment elevation MI 219 (68.44%) and non-ST elevation MI 101 (31.56%). According to the ECG findings, ST elevation, ST depression, T depression, Left Bundle Branch Block and Right Bundle Branch Block were observed.

According to the data, 299 (93.73%) patients were educated regarding the importance of regular clinic follow-up and information on medication, 296 (92.79%) patients were educated on healthy dietary habits and nutritional advice. 85.13% of participants were facilitated with physical activities such as walking, dynamic strength activities and bicycling. 262 (82.13%) patients received counselling on individual disease management and coping strategies and relaxation methods, and motivation strategies. Furthermore, 70% subjects could afford to buy written information books on diet, exercise and lifestyle modification for a small amount of money.

Conclusion

These findings would help to implement preventive measures, including lifestyle modifications, risk factor optimizing and drug treatment. Further, it would assess government expenditures for treating AMI patients in the tertiary care hospital.

Selected References

Abduelkarem, A. R., El-Shareif, H. J., & Sharif, S. I. (2012). Evaluation of risk factors in acute myocardial infarction patients admitted to the coronary care unit, Tripoli Medical Centre, Libya.

Anderson, J. L., & Morrow, D. A. (2017). Acute myocardial infarction. *New England Journal of Medicine, 376*(21), 2053–2064. https://doi.org/10.1056/NEJMra1606915

Bradley, S. M., Borgerding, J. A., Wood, G. B., Maynard, C., & Fihn, S. D. (2019). Incidence, risk factors, and outcomes associated with in-hospital acute myocardial infarction. *JAMA Network Open, 2*(1), e187348. https://doi.org/10.1001/jamanetworkopen.2018.7348

Bucholz, E. M., et al. (2017). Editor's choice—Sex differences in young patients with acute myocardial infarction: A VIRGO study analysis. *European Heart Journal: Acute Cardiovascular Care, 6*(7), 610–622. https://doi.org/10.1177/2048872616661847

D. V. M., & Gupta, S. N. (2002). Presentation characteristics and in-hospital treatment.

Dahmardeh, H., & Sedaghat, M. (2017). Epidemiological investigation of cardiovascular diseases in Khatamol Anbia Hospital in Zahedan city. *Pharmacophore Journal.* http://www.pharmacophorejournal.com

Gehani, A. A., et al. (2014). Association of risk factors with acute myocardial infarction in Middle Eastern countries: The INTERHEART Middle East study. *European Journal of Preventive Cardiology, 21*(4), 400–410. https://doi.org/10.1177/2047487312465525

Griffo, R., et al. (2013). Effective secondary prevention through cardiac rehabilitation after coronary revascularization and predictors of poor adherence to lifestyle modification and medication: Results of the ICAROS Survey. *International Journal of Cardiology, 167*(4), 1390–1395. https://doi.org/10.1016/j.ijcard.2012.04.069

Jamil, G., et al. (2013). Risk factor assessment of young patients with acute myocardial infarction. *AJCD.* Retrieved from https://www.AJCD.us/

Joshi, P., et al. (n.d.). Risk factors for early myocardial infarction in South Asians compared with individuals in other countries. *JAMA Network.* https://jamanetwork.com/

Juárez-Herrera, Ú., & Jerjes-Sánchez, C. (2013). Risk factors, therapeutic approaches, and in-hospital outcomes in Mexicans with ST-elevation acute myocardial infarction: The RENASICA II multicenter registry. *Clinical Cardiology, 36*(5), 241–248. https://doi.org/10.1002/clc.22107

Lee, B. J., et al. (2017). Quality of life and physical ability changes after hospital-based cardiac rehabilitation in patients with myocardial infarction. *Annals of Rehabilitation Medicine, 41*(1), 121–128. https://doi.org/10.5535/arm.2017.41.1.121

Leifheit-Limson, E. C., et al. (2015). Sex differences in cardiac risk factors, perceived risk, and health care provider discussion of risk and risk modification among young patients with acute myocardial infarction: The VIRGO study. *Journal of the American College of Cardiology, 66*(18), 1949–1957. https://doi.org/10.1016/j.jacc.2015.08.859

Masuda, J., et al. (2018). Rural-urban disparity in emergency care for acute myocardial infarction in Japan. *Circulation Journal, 82*(6), 1666–1674. https://doi.org/10.1253/circj.CJ-17-1275

Mercado, M. G., & McConnon, M. L. (2013). Myocardial infarction: Management of the subacute period. *American Family Physician.* http://www.aafp.org/afp

Midence, L., Mola, A., Terzic, C. M., Thomas, R. J., & Grace, S. L. (2014). Ethnocultural diversity in cardiac rehabilitation. *Journal of Cardiopulmonary Rehabilitation and Prevention, 34*(6), 437–444. https://doi.org/10.1097/HCR.0000000000000089

Ögmundsdottir Michelsen, H., et al. (2020). Cardiac rehabilitation after acute myocardial infarction in Sweden – Evaluation of programme characteristics and adherence to European guidelines: The Perfect Cardiac Rehabilitation (Perfect-CR) study. *European Journal of Preventive Cardiology, 27*(1), 18–27. https://doi.org/10.1177/2047487319865729

Peixoto, T. C. A., et al. (2015). Early exercise-based rehabilitation improves health-related quality of life and functional capacity after acute myocardial infarction: A randomized controlled trial. *Canadian Journal of Cardiology, 31*(3), 308–313. https://doi.org/10.1016/j.cjca.2014.11.014

Ralapanawa, U., et al. (2019). Epidemiology and risk factors of patients with types of acute coronary syndrome presenting to a tertiary care hospital in Sri Lanka. *BMC Cardiovascular Disorders, 19*(1). https://doi.org/10.1186/s12872-019-1217-x

Ranasinghe, W. G., et al. (2020). Quality evaluation and future priorities for delivering acute myocardial infarction care in Sri Lanka. *Heart, 106*(8), 603–608. https://doi.org/10.1136/heartjnl-2019-315396

Rathore, V. (2018). Risk factors of acute myocardial infarction: A review. *Eurasian Journal of Medical Investigation.* https://doi.org/10.14744/ejmi.2018.76486

Rauch, B., et al. (2014). Short-term comprehensive cardiac rehabilitation after AMI is associated with reduced 1-year mortality: Results from the OMEGA study. *European Journal of Preventive Cardiology, 21*(9), 1060–1069. https://doi.org/10.1177/2047487313486040

Rehman, S., Li, X., Wang, C., Ikram, M., Rehman, E., & Liu, M. (2019). Quality of care for patients with acute myocardial infarction (AMI) in Pakistan: A retrospective study. *International Journal of Environmental Research and Public Health, 16*(20), Article 3890. https://doi.org/10.3390/ijerph16203890

Roe, M. T., et al. (2010). Treatments, trends, and outcomes of acute myocardial infarction and percutaneous coronary intervention. *Journal of the American College of Cardiology, 56*(4), 254–263. https://doi.org/10.1016/j.jacc.2010.05.008

Wang, Y., et al. (2015). Assessing the quality of care for patients with acute myocardial infarction in China. *Clinical Cardiology, 38*(6), 327–332. https://doi.org/10.1002/clc.22405

West, R. R., Jones, D. A., & Henderson, A. H. (2012). Rehabilitation after myocardial infarction trial (RAMIT): Multi-centre randomised controlled trial of comprehensive cardiac rehabilitation in patients following acute myocardial infarction. *Heart, 98*(8), 637–644. https://doi.org/10.1136/heartjnl-2011-300302

Yandrapalli, S., Nabors, C., Goyal, A., Aronow, W. S., & Frishman, W. H. (2019). Modifiable risk factors in young adults with first myocardial infarction. *Journal of the American College of Cardiology, 73*(5), 573–584. https://doi.org/10.1016/j.jacc.2018.10.084

Thesis reference

Lasanthika Somasiri, B.V.S., A descriptive study on risk factors for and types of curative care and early rehabilitative care provided to patients admitted with acute myocardial infarction to the cardiology unit of the National Hospital Kandy, M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya.

CHARACTERIZATION OF EXTRACELLULAR VESICLES FROM TUBERCULOSIS PATIENT SERA: A POTENTIAL SOURCE FOR BIOMARKER IDENTIFICATION

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Tuberculosis (TB) remains a major global public health challenge. Despite advancements in healthcare, TB continues to affect millions, with an estimated 10.6 million people falling ill and 1.6 million deaths recorded worldwide in 2021. The global incidence rate stands at approximately 132 cases per 100,000 population, and around 1.9 billion people are estimated to be latently infected with TB (LTBI).

In Sri Lanka, tuberculosis (TB) is the second most prevalent infectious disease after dengue, causing approximately 500–600 deaths annually. The estimated national TB burden was 63 cases per 100,000 population in 2021, with a significant gap of 4,000–5,000 undiagnosed or unreported cases. This gap contributes to the continued transmission of *Mycobacterium tuberculosis* (MTB) and an increase in latent TB infection (LTBI) cases. According to available data, nearly a quarter of Sri Lanka's population may be latently infected.

Diagnosing latent TB presents a significant challenge, as no gold-standard diagnostic method currently exists. The two commonly used diagnostic tools—Tuberculin Skin Test (TST)

and Interferon-Gamma Release Assay (IGRA) have limited accuracy, particularly in individuals vaccinated with Bacille Calmette-Guerin (BCG) and those co-infected with human immunodeficiency virus (HIV). In Sri Lanka, the Mantoux test (a form of TST) is widely used, but its specificity is low, particularly in distinguishing MTB from non-tuberculous mycobacteria (NTM) infections. Furthermore, the high BCG vaccination coverage (99%) in Sri Lanka increases the likelihood of false-positive results in children. Immunocompromised individuals, including those with HIV or recovering from COVID-19, may also yield false-negative results due to low CD4+ lymphocyte counts. These diagnostic limitations underscore the urgent need for more accurate and robust approaches for early LTBI detection to reduce TB-related morbidity and mortality.

Recent TB research has focused heavily on identifying reliable biomarkers, particularly those derived from the host. Due to genetic variability across populations, it is crucial to carefully select host biomarkers and apply machine learning tools for accurate analysis. While host markers are valuable, detecting pathogen-specific biomarkers offers a more complete understanding of the interaction between MTB and the human host. However, for tuberculosis, identifying these pathogen specific biomarkers in traditional biological fluids, such as blood or serum, is challenging due to their low abundance.

To address this, attention has shifted to extracellular vesicles (EVs)—small, membrane-bound particles found in fluids like blood, saliva, and urine. These vesicles carry a range of biologically important molecules, including DNA, RNA, proteins, and lipids, and have shown promise as carriers of *M. tuberculosis* specific (MTB-specific) markers. Recent studies have explored the potential of EVs to improve TB diagnosis and screening by revealing both host and pathogen-derived biomarkers.

Therefore, this study focused on the potential of serum-derived EVs for identifying both host and pathogen-specific TB biomarkers using molecular, biophysical, biochemical techniques and machine-learning algorithms as a preliminary attempt. Initially, a cost-effective EV isolation method was used to isolate serum-derived EVs from different TB clinical groups (active TB, latent TB, and household contacts) and healthy samples through polyethylene glycol (PEG) precipitation and filtration. Selected MTB and human-specific transcripts were then detected in these EV samples using reverse transcription quantitative polymerase chain reaction (RT-qPCR). Additionally, the EVs were characterized biophysically and biochemically using dynamic light scattering (DLS) and Raman spectroscopy (RS), a relatively underutilized approach in TB diagnostics. Finally, a machine learning–based analysis was applied to assess MTB and human gene expression patterns in serum-derived EVs and whole blood from active and latent TB patients using publicly available RNA sequencing data, aiming to identify potential TB biomarkers.

Methodology

A total of 111 serum samples were collected from individuals attending the Kandy Chest Clinic. Participants were categorized into four groups: active tuberculosis (ATB, n=26), latent tuberculosis (LTB, n=31), household contacts (HHC, n=32), and healthy controls (HC, n=22). ATB diagnosis was based on clinical or bacteriological evidence, while LTB cases were confirmed by a positive Mantoux test, normal chest X-ray, and absence of TB symptoms or other infections. HHC participants were selected from contact tracing lists and showed negative Mantoux results, whereas healthy controls exhibited no TB exposure, no clinical symptoms, and normal chest X-rays.

Socio-demographic, clinical, and exposure data were collected through an interviewer-administered questionnaire and analyzed using EpiData and SPSS software. Blood samples were collected into serum separator tubes, allowed to clot, and then centrifuged to isolate the serum, which was aliquoted and stored at - 80 °C. A low cost polyethylene glycol (PEG)-based method was used to isolate EVs from serum samples. After a series of centrifugation steps to remove cells, debris, macrovesicles, and apoptotic bodies, the samples were precipitated using an

8% PEG6000 solution and then incubated before undergoing the final centrifugation step. The resulting EV pellets were washed with phosphate saline buffer and filtered before storage. For the dynamic light scattering (DLS) and Raman spectroscopy (RS) analyses, samples were freshly prepared.

The size and polydispersity of EVs were measured using DLS, with 15 samples from each group analyzed under fixed conditions. For morphological analysis, Raman spectroscopy was used to examine EVs under high magnification. RNA was extracted from EVs using the guanidinium thiocyanate–phenol–chloroform method, followed by reverse transcription to complementary DNA (cDNA). RT-qPCR was performed on five MTB transcripts: IS6110, Ag85A, DnaK, GlnA1, GarA, and five human transcripts: CXCL10, CCL24, ABCA1, GBP1, XPO4, across clinical groups. PCR reactions were optimized using specific primers and optimized thermal cycling parameters. Amplicons were verified using melt curve analysis.

For biochemical analysis, EVs from all four groups were subjected to Raman spectroscopy using a 785 nm laser. Raman spectra were collected and pre-processed to remove background noise and interference using extended multiplicative signal correction and rubber band baseline correction before analysis. Spectral data were then analyzed using principal component analysis (PCA) and machine learning algorithms, including k-nearest neighbour (kNN) and random forest (RF). Classification performance metrics, including area under the curve (AUC), accuracy, precision, recall, and specificity, were calculated.

Finally, RNA-sequencing datasets from various geographic cohorts (Spain/Mozambique, India, Sri Lanka) were retrieved for both whole blood and serum-derived exosomes. Sequences were aligned to the human and MTB reference genomes using HISAT2, and expression levels were quantified with StringTie. Differential expression analysis was performed using DESeq2 in R, identifying host and pathogen-specific genes with significant fold changes and p-values. Pathway enrichment analysis was conducted using the Reactome database for human genes and the PANTHER classification system for *M. tuberculosis* MTB genes. Next, protein-protein interaction networks were constructed using STRING, revealing functional associations among differentially expressed proteins. This integrated approach highlights the diagnostic potential of serum-derived EVs and potential RNA biomarkers in distinguishing TB infection states.

Results and Discussion

This study shows the feasibility of isolating EVs from serum samples of TB patients using a cost-effective PEG precipitation and filtration method. The isolated EVs contained sufficient RNA, including both host and MTB-derived transcripts, enabling reliable detection via RT-qPCR. Differences in MTB transcript levels among clinical groups suggest potential prognostic value for TB management. Morphological analysis using DLS revealed distinct EV subpopulations; however, further validation with larger cohorts is needed due to factors like storage conditions and isolation protocols that may affect EV integrity.

Biochemical characterization via RS identified spectral differences associated with nucleic acids, lipids, proteins, and carbohydrates across the clinical groups. Notably, lipid-associated Raman peaks were highest in the latent TB group, indicating potential significance as a biomarker. Multivariate analysis using PCA and machine learning models (Random Forest and kNN) showed good discrimination between LTB and other groups, reinforcing the diagnostic potential of EV-associated signatures.

Additionally, RNA-sequencing and machine learning approaches comparing whole blood and serum-derived exosomes (EXOs) supported the relevance of exosomal RNA in TB biomarker discovery. While whole blood remains a strong source for host biomarkers, EXOs offer a unique advantage by capturing both host and pathogen-derived signatures, crucial for studying intracellular infections like TB. These findings highlight the promise of combining EV-based

methods with rapid, real-time analytical techniques for future TB diagnostics, and emphasize the growing need for exosome-focused transcriptomic studies in TB research.

Conclusion

This study underscores the clinical application of low-cost EV isolation methods combined with real-time diagnostic techniques for TB screening and diagnosis, emphasizing the importance of examining whole blood and exosomes for TB biomarker identification and suggesting that exosomes offer a comprehensive view of host-pathogen interactions.

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Selected References

Lv, L., Li, C., Zhang, X., Ding, N., Cao, T., Jia, X., Wang, J., Pan, L., Jia, H., Li, Z., Zhang, J., Chen, F., & Zhang, Z. (2017). RNA profiling analysis of the serum exosomes derived from patients with active and latent *Mycobacterium tuberculosis* infection. *Frontiers in Microbiology, 8,* 1–10. https://doi.org/10.3389/fmicb.2017.

Neerukonda, S. N., Egan, N. A., Patria, J., Assakhi, I., Tavlarides-Hontz, P., Modla, S., Muñoz, E. R., Hudson, M. B., & Parcells, M. S. (2020). A comparison of exosome purification methods using serum of Marek's disease virus (MDV)-vaccinated and -tumor-bearing chickens. *Heliyon, 6*(12), e05663. https://doi.org/10.1016/j.heliyon.2020.e05663

Pertea, M., Kim, D., Pertea, G. M., Leek, J. T., & Salzberg, S. L. (2016). Transcript-level expression analysis of RNA-seq experiments with HISAT, StringTie and Ballgown. *Nature Protocols, 11*(9), 1650–1667. https://doi.org/10.1038/nprot.2016.095

World Health Organization. (2022a). *Global tuberculosis report*. https://www.who.int/teams/global-tuberculosis-programme

Thesis reference

Bandara, W.R.U.A. (2024). Characterization of Extracellular Vesicles from Tuberculosis Patient Sera: A Potential Source for Biomarker Identification. MPhil thesis, Postgraduate Institute of Science, University of Peradeniya, Sri Lanka.

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EPIDEMIOLOGY, CLINICAL CHARACTERISTICS AND OUTCOMES RELATED TO MULTISYSTEM INFLAMMATORY SYNDROME (MIS-C) CAUSED BY SARS-COV-2 INFECTION IN CHILDREN: A CASE SERIES FROM A TERTIARY CARE HOSPITAL IN SRI LANKA

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The Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection has rapidly spread all over the world since it was first identified in China in December, 2019, with subsequent epicenters being recognized in Europe and the U.S.A. According to previous reports of SARS-CoV-2 infection, young children were disproportionately spared from infection, but it remains unclear if this is due to a lack of detection because of predominantly asymptomatic or mild disease in this age group. In April 2020, a novel syndrome in children termed “Multisystem Inflammatory Syndrome in Children” (MIS-C) with likely relation to SARS-CoV-2 infection was first described. Initial reports surfaced in the UK and Italy, followed by New York and other parts of the U.S.A. MIS-C is generally curable and rarely happens, but a certain lack of knowledge could make it severe in the long term. As it is a rare condition, most children who have it improve with medical treatment. Due to the limited number of studies and no research available related to the Epidemiology of Sri Lankan children who have been diagnosed as MIS-C, there is a barrier to efficiently treating and identifying those patients early before becoming critically ill. As the majority of children in Sri Lanka have not been vaccinated, and in the future people will have to live with COVID-19 infection, it will be very valuable to establish the epidemiological link and clinical characteristics of Sri Lankan children who are diagnosed with MIS-C. However, limited data exists regarding the epidemiology

and outcomes of MIS-C in Sri Lankan children, creating challenges in early detection and management. This study aimed to address this gap by documenting the clinical features, epidemiological factors, and outcomes of MIS-C cases in a tertiary care setting in Sri Lanka.

The following specific goals were set for the study to accomplish the main goal:

1. To describe the socio-demographic factors of children diagnosed with MIS-C.

2. To outline the clinical characteristics and outcomes of MIS-C cases.

3. To identify comorbidities associated with MIS-C.

4. To determine the mean time between COVID-19 infection and MIS-C onset.

5. To assess epidemiological factors influencing MIS-C severity.

Methodology

A retrospective case series study was conducted at Sirimawo Bandaranayake Specialized Children's Hospital, Peradeniya, Sri Lanka, from January 2021 to January 2023. A total of 35 children diagnosed with MIS-C according to CDC-2019 criteria were included using consecutive sampling. Data were collected from medical records using a structured format. Analysis was performed using SPSS, applying descriptive statistics and Pearson's Chi-square test for associations ($p<0.05$). Ethical clearance was obtained from the Ethical Clearance Committee, Postgraduate Institute of Science, University of Peradeniya. Data was entered and analyzed using SPSS. Pearson's Chi-square test was performed for significance testing among categorical data. Descriptive statistics were used to summarize the data. $P < 0.05$ was considered as statistically significant.

Results and Discussion

The median age of enrolled cases was 4.6 years while mean (±SD) weight was 14.19 kg±10.42 kg. The majority of the studied cases were Sinhala (85.7%). 74.3% cases represented the low income social class. Iron deficiency anemia was the most prevalent comorbidity (22.9%). Major clinical manifestations were fever (≥24 hours) (100%), Gastro Intestinal Symptoms (88.6%), skin rashes (42.9%) while Ear pain (2.9%) and Neck pain (11.4 %) were reported as uncommon symptoms compared to previous study. From the total cases 62.9% were admitted to ICU and 86.7% cases needed artificial ventilation. Inotropic supports were administered for 45.7 % cases. Hyperkinesia of heart was the commonest 2D Echo finding among 16 cases with 45.7% percentage.

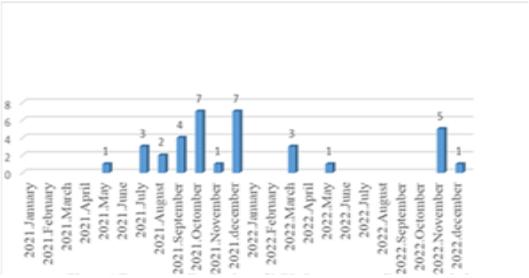

Figure 1. Frequency distribution of MIS-C cases according to admission date from 1st of January, 2021 2023

Out of the total cases 16 (45.7%) cases had completely recovered, 37.1% had acute illness recovery with organ dysfunction and 17.1% were death. There were 45.7% mild MIS-C cases and the number of moderate MIS-C cases were 07 (20%). Twelve cases were categorized into severe MIS-C category. There was a significant association ($p<0.05$) between residence and clinical severity of the disease.

Conclusion

The time period between September to December, children from low-income families, residents from rural areas and a median age of 4.6 years were identified as epidemiological factors for developing MIS-C. Iron deficiency anemia among children should be properly

treated. Further, it outlines the need of early detection of disease and improving sophisticated health care access to children who are living in rural areas and proper health education programs.

This study highlights the urgent need for early detection of MIS-C, timely referral to specialized care, and improved access to pediatric intensive care in rural areas. Addressing iron deficiency anemia in children may reduce disease burden. The findings provide valuable epidemiological insights to guide MIS-C management in Sri Lanka.

Selected References

CDC COVID-19 Response Team. (2020). Coronavirus disease 2019 in children—United States, February 12–April 2, 2020. *Morbidity and Mortality Weekly Report, 69*, 422–426.

Parri, N., Lenge, M., & Buonsenso, D. (2020). Children with COVID-19 in pediatric emergency departments in Italy. *New England Journal of Medicine.*

Riphagen, S., Gomez, X., Gonzalez-Martinez, C., Wilkinson, N., & Theocharis, P. (2020). Hyperinflammatory shock in children during COVID-19 pandemic. *Lancet.*

Verdoni, L., Mazza, A., Gervasoni, A., Martelli, L., Ruggeri, M., Ciuffreda, M., Bonanomi, E., & D'Antiga, L. (2020). An outbreak of severe Kawasaki-like disease at the Italian epicentre of the SARS-CoV-2 epidemic: An observational cohort study. *Lancet.* https://doi.org/10.1016/S0140-6736(20)31103

Thesis reference

Kumari, K.C.N (2024). Epidemiology, clinical characteristics and outcomes related to Multisystem Inflammatory Syndrome caused by SARS CoV-2 infection in children; A Case Series from tertiary care hospital in Sri Lanka, M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya.

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INVESTIGATION OF MOTHS (LEPIDOPTERA) AS PESTS ON SELECTED AGRICULTURAL LANDS IN ETIGALA, MATALE

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Moths and butterflies are those, which belong to the order Lepidoptera in the Class Insecta of the Phylum Arthropoda. In numbers, this order is exceeded only by the order Coleoptera (beetles), and it has been estimated that the fauna of Lepidoptera is more than 160,000 species worldwide.

Moths can be easily distinguished from butterflies by many morphological characteristics and behaviours. The shape of the antennae is the best way to distinguish moths from butterflies. Moths have simple thread-like or 'feathery' antenna without a club, whereas butterflies have a thickened club or hook on the tip of the antenna, and never have feathery. Moths have a frenulum, a wing-coupling device, which is not present in butterflies. The frenulum helps join the forewing to the hindwings, allowing the two wings to work together during flight. Butterflies are primarily diurnal, but moths are mostly nocturnal, and when resting, butterflies fold their wings above their backs, but moths spread their wings out to the two sides.

When compared with butterflies, most moth species are somewhat neglected. However, the smaller species are of economic significance, while a greater interest is being shown recently in micro Lepidoptera, especially those families that attack crops and ornamental plants or those likely to assist in the control of weeds.

Different moth species influence cultivations in different ways. Also, some moth species are very harmful to the cultivations, while some do not harm. Also, some stages of the life cycle of moths cause problems for farmers, while others do not.

Wiltshire is the mountain that stands behind the Aluvihare Temple in Matale. It is also called Aluvihare Kanda or Etigala, which is the southern part of the Knuckles. Etigala is located in the southern part of the Knuckles Range in Sri Lanka. Knuckles, including Wiltshire, was declared a conservation forest in April 2000 and subsequently, as a "National Man and Biosphere

Reserve" by the Central Environment Authority. For this research, four agricultural areas were randomly selected around the Etigala area. The main reasons for selecting these agricultural areas were their proximity to a forest patch, where the effect of the moth on agriculture can be easily identified. Also, the soil type and vegetation were similar in all four areas, which were situated between human settlements. The research was carried out from 27th December 2019 to 30th July 2020.

Hence, this study was focused on assessing the positive and negative roles of moths on agriculture, as well as to identify the different effects of the forest cover to the diversity of moths and on agriculture.

The main objective was to identify whether moths are major pests in agriculture.

The following specific goals were set for the study to accomplish the main goal:

I. To study the biodiversity of moths in and around the Wiltshire and Knuckles areas.
II. To study the effect of moths as major pests in Sri Lanka.
III. To identify the presence of moth species that are considered major pests in Sri Lanka.
IV. To identify and study the local knowledge on the control of moths as pests.
V. To identify and study the pest management methods used to overcome the ill-effects of moths on agriculture.

Methodology

The collection of data was carried out under a few methodologies. Both primary and secondary data were used for the study. Primary data collected through the questionnaire were used as independent variables, while post-impacts and ecotourism potentials were used as dependent variables. To meet the objectives of the research, a field observation survey was conducted. In addition, secondary data such as books, journals, and websites were used to gather information about moth taxonomy and moth biology. Considering these, three different methodologies were followed, *viz*, the sweep net method, light trap method, and the questionnaire method.

A sweep net made using domestic mosquito netting was used to catch the moths in agricultural fields, with dimensions of the net being 38 cm in the net ring and 91 cm in the handle. A sweep net was used three times per day, only during daytime, around 7 a.m. to 8 a.m., 11 a.m. to 12 noon, and 3 p.m. to 4 p.m. Photographs of the relevant life cycle stage of the moths were taken before releasing them back to the environment. Species were later identified with the help of checklists and other websites.

Most of the moth trap designs were not particularly suitable for use in tropical conditions, because they are too small to cope with the large catches (Ganiger *et al*, 2018; Andrews, 1980). To overcome this, a light sheet with a white 10′ × 6′ cloth was fixed between two wooden poles, and the bulb was placed in the middle, so that the entire sheet was brightly illuminated. Moths were collected from both the Wilshire Forest edge and the agricultural fields of the study area.

Two cloth sheets were used in each of the sites, one facing towards the Wiltshire range and the other facing the opposite side, to identify the effect of the forest patch on the moth diversity. The captured species were photographed and released back to the environment, and later identified using the checklist and other online websites.

A questionnaire was prepared to collect data about the moths and the data to be collected from the farmers. To identify the peak activity of the adult moths and caterpillars that may harm the crops, farmers were questioned in both mornings and evenings.

The four agricultural lands selected for the research were

- Pahalawela area of Warakamura
- Thotagamuwa area of Aluvihare
- Ellepola area of Palapathwala

- Thenna area of Kumbiyangoda

Results and Discussion

A total of 45 moths were collected and found to be in 25 genera and 7 families. A larger number of Macrolepidoptera were recorded than Microlepidoptera due to light traps and sweep nets. It is also difficult to identify Microlepidoptera with those trapping and collection methods (Praveen, 2018). The Microlepidoptera superfamilies are Tineoidea, Tortricoidea, Zygaenoidea, Thyridoidea, and Hyblaeoidea, while the families are Bombycidae, Crambidae, Erebidae, Eutelidae, Geometridae, Uraniidae and Noctuidae.

A total of 15 species of moths were observed in the agricultural land. The land was cultivated with paddy, corn, brinjal, okra, and winged bean. Moths belonged to the families: Noctuidae, Geometridae, Arctiidae, Nolidae, Tortricidae, and Erebidae. In the morning hours, from 7 a.m. to 8 a.m., a few numbers of caterpillars were recorded from leaves, leaf sheaths, stems, and flowers. However, from 11 a.m. to 12 noon, more caterpillars were recorded from the cultivation land. The majority of caterpillars were collected from the leaf sheaths of paddy and corn. Corn was the severely damaged crop from the caterpillars of the species *Spodoptera frugiperda*, where they were found in large numbers on corn ears, tassels, and immature corn pods. Other than *S. frugiperda*, corn ears were considerably attacked by aphids.

A total of 21 species of moths were observed in the agricultural lands. These lands were cultivated with several patches of paddy, tomato, chili, okra, pennywort, and spiny lasia (*Lasia spinosa*). Moths belonged to the major families: Noctuidae, Erebidae, Nolidae, Tortricidae, Arctiidae, and several unidentified minor moth families.

In the morning hours from 7 a.m. to 8 a.m., a few numbers of caterpillars were recorded from leaves, stems, flower inflorescences, and pods. From 11 a.m. to 12 noon, caterpillar numbers were very high, particularly from paddy, okra, and tomato. Two species of moths, *Spodoptera mauritia* and *Parapoynx stagnalis* were recorded in even numbers. Plants attacked by S. *mauitia* were characterized by skeletonized leaves, shot holes, and dieback stems. Plants attacked by P. *stagnalis* were characterized by ladder-like skeletonized tissues in leaves. Caterpillars were hand-picked when they cut leaf tips to make leaf cases. However, more damage has been done to the paddy by P. *stagnalis* towards the Wiltshire forest patch. Damage done by S. *mauritia* was observed in the plants grown towards the roadside. Apart from that, several immature instars and adults were observed from weeds such as *Megathyrsus maximus*, *Fimbristylis miliacea,* and *Tridax procumbens*.

A total of 10 species of moths were observed in the agricultural lands. These lands were cultivated with several patches of paddy, corn, long beans, chili, finger millet, and cowpea. Moths belonged to the major families: Noctuidae, Erebidae, and Crambidae, and several minor families. In the morning hours from 7 a.m. to 8 a.m., a few numbers of caterpillars were recorded from leaves, leaf sheaths, stems, and pods, especially S. *frugiperda*. From 11 a.m. to 12 noon, caterpillar numbers were very high, particularly from paddy and corn.

However, the number of moths in the cultivated lands was very low when compared with the other three agricultural lands. The majority of caterpillars were recorded during the seedling stage of corn and paddy, where some individuals were observed inside the leaf sheaths with frass and deep in the stem. Tassels were less affected by caterpillars. The number of caterpillars was low during the evening from 3 p.m. to 4 p.m. Some moths were recorded from light traps but were absent in the crops.

A total of 23 species of moths were observed in the agricultural lands. The land was cultivated with several patches of paddy, corn, okra, brinjal, and chili. Moths belonged to the major families: Noctuidae, Arctiidae, Erebidae, Geometridae and several unidentified minor moth families.

In the morning hours from 7 a.m. to 8 a.m., a few numbers of caterpillars were recorded from

leaves, stems, flower inflorescences, and corn ears. From 11 a.m. to 12 noon, caterpillar numbers were very high, particularly from paddy and corn. Paddy was affected by *Cnaphalocrocis medinalis,* and corn was severely affected by *Spodoptera frugiperda*. C. *medinalis* were collected from a sweep net during the daytime from both paddy and chili plants. However, caterpillars were identified only from paddy plants.

The corn plantation was severely affected by S. *frugiperda* caterpillars. There were egg masses on the underside of several leaf sheaths where first instars were recorded in many plants. Many instars were identified from the whorl and corn ear. When the same cultivation was observed in the evening, the damage was heavy, and many instars were observed deep in the whorl with a lot of yellowish brown frass.

Conclusion

The different types of crops that were attacked by moths, paddy, and corn were identified. Concerning the life cycle of the moths, it was identified that the larval stage was identified as the most attacking stage with respect to the other stages. In this study, it was identified that, in May and June, the activity of moths increased, especially at the onset of the monsoon. Daytime was identified as the sessions in which the moth's activity was high. The adult stage of moths was usually nocturnal, and the caterpillars were crepuscular and were active during the day as well. It was able to collect many caterpillars from 11 a.m. to 4 p.m.

Severe attack was identified during the early stages of the crop cycle, such as the seedling and pre-flowering stages. The climatic parameters between the four agricultural lands did not depict a significant difference, but relative humidity was observed to have the highest impact on the changes in abundance of moths, with low temperature having the least.

It was identified that many caterpillars are borers that destroy the stem of the crop internally. While most of the caterpillars attacked the stem, a few caterpillars were observed in the leaves and the crown. Natural enemies such as greater coucals, flycatchers, lizards, monitors, and skinks played a major role in controlling the adults as well as caterpillars, particularly in forest edges.

It is noted that moth populations were low in numbers when other pests were abundant in and around the cultivated land. There were only two species of moths, which caused a significant loss to the harvest: *viz.*, *Cnaphalocrocis medinalis* and *Spodoptera frugiperda*. They caused heavy infestations and significant loss in crop harvests. Paddy and corn were largely affected in almost all selected agricultural lands. Many moth species caused insignificant loss to cultivated crops.

The majority of farmers thought that moths were the most devastating pests in Sri Lankan agriculture. But it is revealed that not all moths and caterpillars are agricultural pests. However, the conclusion could be that the damage caused by moths is rather less when compared with the damage caused by other insects

Selected References

Barlow, H. S. (1982). *An introduction to the moths of South East Asia.* Malayan Nature Society.

Ghosh, S. K., & Alfred, J. R. B. (2003). *Insecta: Lepidoptera: Heterocera: Geometridae.* State Fauna Series, 9, 217–342.

Gurule, S. A., & Nikam, S. M. (2013). The moths (Lepidoptera: Heterocera) of northern Maharashtra: A preliminary checklist. *Journal of Threatened Taxa, 5*(12), 4693–4713.

Kendrick, R. C. (2018). *Moths (Insecta: Lepidoptera) of Hong Kong* (PhD Thesis). University of Hong Kong. 47 plates, 1–660 pp.

Wijeratne, H. M. P. A., Shama, A. F., Noyalin, M., & Wijeyamohan, S. (2021). A preliminary study on the moth diversity (Lepidoptera) of University of Vauniya, Pampaimadu, Sri Lanka. *Vavuniya University International Research Conference*

Thesis reference

Jayaweera, G.G.G.S., Investigation of moths (lepidoptera) as pests on selected agricultural lands in Etigala, Matale, M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya.

PREVALENCE AND FACTORS ASSOCIATED WITH DIABETES AMONG ADULTS 35 YEARS AND ABOVE: A SECONDARY ANALYSIS OF THE PRIMARY HEALTH CARE SYSTEM STRENGTHENING PROJECT'S DATASET OF DIVISIONAL HOSPITAL POLGAHAWELA, SRI LANKA

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Diabetes is one of the fastest-growing health concerns in the world today. It affects more than 500 million people globally, and this number is expected to keep rising. In countries like Sri Lanka, the burden is especially worrying. Many people live with diabetes without knowing they have it. This leads to serious complications that could otherwise be prevented with early diagnosis and care.

Sri Lanka is now considered a hotspot for diabetes in South Asia. While several national studies have shown the growing impact of this disease, there is limited data from smaller regions like the North Western Province. That is why this study focused on the Polgahawela area, where there had been very little information on how many people are affected and what risk factors might be involved.

In response, this study aimed to assess the prevalence and associated factors of diabetes mellitus among adults aged 35 years and above in 26 Grama Niladhari (GN) divisions within the Polgahawela Medical Officer of Health (MoH) area. The study used data from a government health initiative called the Primary Health Care System Strengthening Project conducted between March 2020 and February 2021. This project was supported by the Ministry of Health and the World Bank, aiming to improve the management of non-communicable diseases at the primary care level.

Methodology

The study involved 2,661 adults aged 35 and above who voluntarily took part in health screening at the Healthy Lifestyle Clinics at the Divisional Hospital Polgahawela. These screenings were carried out by trained healthcare professionals using standardized protocols. The combination of questionnaire data, physical measurements, and laboratory results allowed the

researcher to analyse how various social, behavioural, and medical factors were linked to diabetes.

Results and Discussion

Out of the 2,661 people who took part, about one in five (20.10%) had diabetes. What is even more concerning is that almost half of these people were unaware they had the condition until they were screened. This shows how important routine checkups are, especially in rural or semi-urban communities. The highest number of cases was found in the 55 to 64 age group. Although women made up most of the study participants, diabetes was more common among men. Waist circumference also played a big role. People with larger waist circumference were more likely to have diabetes. Other health issues were also linked to diabetes. People with high blood pressure were nearly three times more likely to have diabetes. Kidney function, as measured by creatinine levels, was also related. Those with impaired kidney function were at a higher risk. Lifestyle habits such as alcohol use showed a link with diabetes, but smoking and betel chewing did not show a strong connection in this group. It is possible that these habits are underreported or that the effects vary by population.

These results highlight the need for more health screening programs at the community level. Many people who have diabetes are not aware of it. Early detection can make a big difference in preventing complications like heart disease, kidney failure, and vision loss. The findings also point to specific groups who should be prioritized. Older adults, men, people with high waist measurements, and those with high blood pressure or early signs of kidney issues need extra attention. Regular checkups, healthier diets, more physical activity, and targeted health education could help reduce the impact of diabetes in areas like Polgahawela and beyond.

Conclusion

This study offers valuable evidence for health planners in the North Western Province. It shows the need for better screening, community outreach, and education. The Healthy Lifestyle Clinics are a great starting point, but more people need to be encouraged to attend them regularly. As Sri Lanka faces a rising wave of diabetes, this research work will aid in identifying people at risk. By being aware and having better access to primary care, the disease can be identified at an early stage and therefore preventive measures could be taken to avoid long-term effects.

Selected References

Katulanda, P., Constantine, G. R., Mahesh, J. G., Sheriff, R., Seneviratne, R. D., Wijeratne, S., Wijesuriya, M., McCarthy, M. I., Adler, A. I., & Matthews, D. R. (2008). Prevalence and projections of diabetes and pre-diabetes in adults in Sri Lanka—Sri Lanka Diabetes, Cardiovascular Study (SLDCS). *Diabetic Medicine: A Journal of the British Diabetic Association, 25*(9), 1062–1069. https://doi.org/10.1111/j.1464-5491.2008.02523.

Katulanda, P., Rathnapala, D., Sheriff, R., & Matthews, D. R. (2012). Province and ethnic specific prevalence of diabetes among Sri Lankan adults. *Sri Lanka Journal of Diabetes Endocrinology and Metabolism, 1*(1), 2. https://doi.org/10.4038/sjdem.v1i1.4180

Pinidiyapathirage, M. J., Kasturiratne, A., Ranawaka, U. K., Gunasekara, D., Wijekoon, N., Medagoda, K., Perera, S., Takeuchi, F., Kato, N., Warnakulasuriya, T., & Wickremasinghe, A. R. (2013). The burden of diabetes mellitus and impaired fasting glucose in an urban population of Sri Lanka. *Diabetic Medicine: A Journal of the British Diabetic Association, 30*(3), 326–332. https://doi.org/10.1111/dme.12013

Prasad Tharu, B., & Tsokos, C. P. (2017). A statistical study of serum cholesterol level by gender and race. *Journal of Research in Health Sciences, 17*(3), 386.

Rannan-Eliya, R. P., Wijemunige, N., Perera, P., Kapuge, Y., Gunawardana, N., Sigera, C., Jayatissa, R., Herath, H. M. M., Gamage, A., Weerawardena, N., Sivagnanam, I., Dalpatadu, S., Samarage, S., Samarakoon, U., Samaranayake, N., Pullenayegam, C., Perera, B., & SLHAS Collaborators. (2023). Prevalence of diabetes and pre-diabetes in Sri Lanka: A new global hotspot—Estimates from the Sri Lanka Health and Ageing Survey 2018/2019. *BMJ Open Diabetes Research & Care, 11*(1), e003160. https://doi.org/10.1136/bmjdrc-2022-003160

Thekkur, P., Fernando, M., Nair, D., Kumar, A. M. V., Satyanarayana, S., Chandraratne, N., Chandrasiri, A., Attygalle, D. E., Higashi, H., Bandara, J., Berger, S. D., & Harries, A. D. (2022). Primary health care system strengthening project in Sri Lanka: Status and challenges with human resources, information systems, drugs and laboratory services. *Healthcare (Basel, Switzerland), 10*(11), 2251. https://doi.org/10.3390/healthcare10112251

Wijewardene, K., Mohideen, M. R., Mendis, S., Fernando, D. S., Kulathilaka, T., Weerasekara, D., & Uluwitta, P. (2005). Prevalence of hypertension, diabetes and obesity: Baseline findings of a population-based survey in four provinces in Sri Lanka. *The Ceylon Medical Journal, 50*(2), 62–70. https://doi.org/10.4038/cmj.v50i2.1571

Thesis reference

Karunarathna, E.J.N., Prevalence and factors associated with diabetes among adults 35 years and above: a secondary analysis of the primary health care system strengthening project's dataset of divisional hospital Polgahawela, Sri Lanka, M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya.

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PREVALENCE, BREEDING PREFERENCE, INSECTICIDE RESISTANCE AND NOVALURON SUSCEPTIBILITY OF DENGUE VECTOR MOSQUITOES *Aedes aegypti* AND *Aedes albopictus*

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Dengue has become a major public health concern in Sri Lanka, with reported cases increasing over 20-fold in the past two decades (Malavige et al., 2021). This surge is attributed to changes in dengue virus serotypes, shifting population immunity, urbanization, increased human mobility, and vector behavior (Zeng et al., 2021; WHO, 2023). *Aedes aegypti*, the primary vector, predominates in urban areas, while *Aedes albopictus* is more common in semi-urban and rural settings.

Understanding breeding site preference along with climatic and physicochemical factors that influence population dynamics of these vectors is essential to predict patterns of mosquito abundance and dengue transmission. Microhabitat measures, such as water quality parameters, can significantly influence vector survival and viral development. This study aimed to address the knowledge gaps by identifying productive breeding containers and evaluating the influence of environmental variables on vector population dynamics. These insights are critical for developing targeted and sustainable larval source reduction strategies.

Additionally, the study assessed the efficacy of Novaluron, an eco-friendly but underutilized insect growth regulator (IGR), against local *Aedes* populations to establish its potential integration into vector control programs.

Given the growing challenge of insecticide resistance (Karunaratne et al., 2018), the study also investigated resistance mechanisms, focusing on enzyme-mediated insecticide detoxification pathways in both larval and adult stages. A better understanding of the mechanisms underlying insecticide resistance of dengue vectors will support evidence-based dengue vector management.

The general objective of the study is to investigate aspects of larval breeding ecology and insecticide resistance mechanisms in dengue vector mosquitoes, as well as to evaluate the efficacy of Novaluron against dengue larvae, with a focus on identifying effective vector control measures.

Specific objectives are:

01.To determine the species composition, seasonal abundance, and distribution of dengue vector mosquitoes in selected localities in the Kurunegala District

02. To examine the breeding site preferences, the co-existing pattern of the larvae of *Ae. aegypti* and *Ae. albopictus*, and the physico-chemical characteristics of the larval habitats of these mosquitoes.

03. To determine the status of resistance and underlying resistance mechanisms in different life stages of dengue vector mosquitoes to commonly used insecticides.

04. To evaluate the efficacy of the larvicidal insect growth regulator (IGR) Novaluron against *Ae. aegypti* and *Ae. albopictus*.

Methodology

The study was conducted in three selected localities in the Kurunegala District. The study sites were dengue high-risk areas as identified by epidemic prevalence data for the previous five-year period (2013–2018). Field surveys were carried out in selected areas, and ovitraps and larval dipping methods were used to collect immature stages. Standard larval indices, House Index (HI), Container Index (CI), Breteau Index (BI), and the ovitrap index (OVI) were calculated to determine vector prevalence. Correlation analysis and stepwise regression analysis were performed to determine the relationship of these indices with the weather parameters.

Breeding site characterization was done using a larval survey, and data were recorded according to the breeding container, material, and place. Water quality analyses were done for different container types and different material types of the containers.

Insecticide resistance was evaluated using WHO standard bioassay protocols against commonly used insecticides, including the larvicide temephos and organophosphate and pyrethroid adulticides (WHO, 2022). Biochemical assays were conducted to detect the activity profiles of detoxification enzymes, esterases, GSTs, and monooxygenases (WHO, 1998). Data were subjected to probit analysis and ANOVA to compare susceptibility levels between species and locations.

Susceptibility to Novaluron was tested by laboratory bioassays using 3rd instar larvae of both vector species. Inhibition of adult emergence (IE50 and IE99), and the lethal concentrations (LC_{50} and LC_{90}) were calculated (WHO, 2016). In semi-field experiments, the residual effect of Novaluron on the 3rd instar *Ae. aegypti* larvae were assessed in two different types of water storage containers.

Results and Discussion

Monthly ovitrap and larval surveys revealed that *Ae. aegypti* was mainly breeding indoors and was restricted primarily to urban areas. *Aedes albopictus* was present in all three areas (i.e. urban, semi-urban, and rural), breeding both indoors and outdoors. Strong correlations were found between OVI and relative humidity, and between BI and rainfall. Prediction models of high accuracy were developed using BI, OVI, and relative humidity with a one-month lag period to predict *Ae. albopictus* population dynamics and potential dengue outbreaks.

Plastic containers were the most common breeding sites (urban: 56.5±4.6%, semi-urban: 48.9±8.56%, rural: 44.9±8.6%). *Aedes aegypti* mostly preferred gutters [Breeding Preference Ratio (BPR = 3.89)], while *Ae. albopictus* favoured tires (BPR = 4.56). Breeding preferences were influenced by pH, total dissolved solids, and alkalinity of the breeding site.

Resistance studies revealed that both species from Colombo were resistant to common synthetic insecticides with elevated activities of insecticide-metabolising enzymes. *Aedes aegypti* larvae were more resistant to insecticides than *Ae. albopictus* larvae. Also, the mechanisms of insecticide resistance were better developed in adults than in larvae. Kaplan-Meier survival analysis showed that *Ae. aegypti* larvae had shorter development times than those of *Ae. albopictus.*

Insect Growth Regulator Novaluron offers an alternative to conventional synthetic insecticides. Larvae exposed to Novaluron (Rimon EC10) revealed that LC_{50} & LC_{99} were respectively 0.047-0.049 ppm & 0.144-0.151 ppm for 7 days and 0.002-0.005 ppm & 0.006-0.01 ppm for 14 days. IE50 & IE99 were 0.0003-0.0004 ppm & 0.0009-0.001 ppm for 14 days. Under semi-field conditions, IE99 at 0.001 ppb was effective for 2 months and 0.01 ppb for 3 months, achieving 89-95% inhibition of adult emergence. Reducing the Novaluron field dosage from the prescribed 200 ppm by 100 times or more is recommended. In summary, the outcome of the present study significantly contributes to our understanding of the distribution, breeding preference, life span, and insecticide resistance of dengue vectors. The findings offer valuable insights for developing targeted interventions, including optimization of the use of eco-friendly IGR Novaluron for dengue vector control.

Conclusion

Aedes albopictus emerged as the dominant dengue vector across urban, semi-urban, and rural settings, while *Ae. aegypti* was confined to urban areas but showed faster development and greater survival. Discarded plastic containers and tyres were key breeding sites, with both species adapting well to varied water conditions. Environmental factors such as rainfall and humidity significantly influenced vector dynamics, and predictive models developed in this study offer useful tools for early outbreak warnings. Insecticide susceptibility varied by location, with higher resistance in Colombo populations due to increased insecticide-metabolizing enzyme activity. Novaluron was effective at much lower concentrations, indicating the need to reassess current recommended higher field dosages to avoid environmental pollution and economic impacts.

Selected References

Malavige, G. N., Jeewandara, C., Ghouse, A., Somathilake, G., & Tissera, H. (2021). Changing epidemiology of dengue in Sri Lanka—Challenges for the future. *PLoS Neglected Tropical Diseases, 15*(8), 24–37.

World Health Organization. (2022). *Standard operating procedure for testing insecticide susceptibility of adult mosquitoes in WHO tube bioassays.*

World Health Organization. (2023). *Dengue in Southeast Asia.* https://www.who.int/southeastasia/health-topics/dengue-and-severe-dengue

Zeng, Z., Zhan, J., Chen, L., et al. (2021). Global, regional, and national dengue burden from 1990 to 2017: A systematic analysis based on the global burden of disease study 2017. *Clinical Medicine, 32.*

Publications

Herath, J. M. M. K., Abeyasundara, H. T. K., de Silva, W. A. P. P., Weeraratne, T. C., & Karunaratne, S. H. P. P. (2022). Weather-based prediction models for the prevalence of *dengue Aedes aegypti* and *Ae. albopictus. Journal of Tropical Medicine, 1*(1), 1–10. https://doi.org/10.1155/2022/4494660

Herath, J. M. M. K., de Silva, W. A. P. P., Weeraratne, T. C., & Karunaratne, S. H. P. P. (2024). Breeding habitat preference of the dengue vector mosquitoes *Aedes aegypti* and *Aedes albopictus* from urban, semiurban, and rural areas in Kurunegala District, Sri Lanka. *Journal of Tropical Medicine, 29.* https://doi.org/10.1155/2024/4123543

Herath, J. M. M. K., de Silva, W. A. P. P., Weeraratne, T. C., & Karunaratne, S. H. P. P. (2024). Efficacy of the insect growth regulator novaluron in the control of dengue vector mosquitoes *Aedes aegypti* and *Ae. albopictus. Scientific Reports, 14,* 1988. https://doi.org/10.1038/s41598-024-52384

Herath, J. M. M. K., de Silva, W. A. P. P., Weeraratne, T. C., & Karunaratne, S. H. P. P. (2024). Stage-specific insecticide susceptibility and life-table analysis of the dengue vector mosquitoes *Aedes aegypti* and *Ae. albopictus. Ceylon Journal of Science, 53*(2), 161–170.

Thesis reference

Herath, J.M.M.K. (2025). Prevalence, breeding preference, insecticide resistance, and novaluron susceptibility of dengue vector mosquitoes *Aedes aegypti* and *Aedes albopictus*. PhD Thesis, Postgraduate Institute of Science, University of Peradeniya.

Institutions where research was carried out

Department of Zoology
Faculty of Science
University of Peradeniya
Peradeniya
Sri Lanka

Entomological Surveillance Unit
Office of the Regional Director of Health
Kurunegala

PROPORTION AND FACTORS ASSOCIATED WITH HYPERTENSION AMONG PARTICIPANTS OF THE PRIMARY HEALTH CARE STRENGTHENING PROJECT: DIVISIONAL HOSPITAL POLGAHAWELA, SRI LANKA

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Hypertension, more commonly known as high blood pressure and often referred to as the "silent killer," is one of the most widespread and dangerous health conditions worldwide. It is a leading cause of illness and premature death, often remain unnoticed until serious complications occur. In Sri Lanka, the prevalence of high blood pressure is steadily rising, driven by an aging population, sedentary lifestyles, dietary changes, and rapid urbanization. National health surveys indicate that nearly one in three Sri Lankan adults lives with hypertension. However, these figures are often based on broad population samples and may not reflect the specific challenges in smaller communities. Local data are essential for designing effective health interventions, yet many regions still lack detailed studies. To help address this gap, our study focused on Polgahawela in Sri Lanka's North Western Province, using data from a community health screening conducted under the Primary Health Care System Strengthening Project (PSSP). This national initiative, led by Sri Lanka's Ministry of Health with support from the World Bank, aims to improve the prevention and management of non-communicable diseases at the primary care level. As part of the program, a Healthy Lifestyle Clinic was established at the Divisional Hospital in Polgahawela, where adults aged 35 and above were invited to attend free health screenings between March 2020 and February 2021.

Methodology

Among the 2,661 adults who took part in the screening, 23% were found to have hypertension. Approximately 6% were newly diagnosed at the clinic, while others already had a history of high blood pressure. In addition, nearly 26% were considered to be in the "pre-hypertensive" range.

Results and Discussion

The study revealed that the likelihood of having hypertension increased significantly with age. Both men and women showed this trend, and among people over the age of 65, nearly half had high blood pressure. This pattern is consistent with international studies and is largely due to the natural aging of blood vessels and a reduction in the body's ability to regulate blood pressure effectively. Obesity also emerged as a major contributing factor. Participants with higher body mass index or increased waist circumference were more likely to have hypertension. This was especially evident among women in the study, where central obesity showed a strong association with high blood pressure. The study also found that alcohol consumption had a significant association with hypertension in women. While men in Sri Lanka are generally more likely to consume alcohol, the findings suggest that alcohol use may have a stronger impact on blood pressure among women. Elevated serum creatinine levels, an indicator of kidney function, were also more common among hypertensive women, suggesting a possible link between kidney health and high blood pressure in this group.

These results reinforce the urgent need to address hypertension at the community level. In many Sri Lankan towns and villages, regular health checks are rare, and people often do not know they have high blood pressure until they experience serious complications. Community screening programs like the one at Polgahawela offer a valuable opportunity to detect health risks early and guide people toward better health. By identifying those at risk before symptoms appear, healthcare providers can offer targeted advice, encourage healthy habits, and begin treatment where necessary.

It is important to acknowledge some limitations of the study. Because participation in the health screening program was voluntary, it is possible that individuals who are more health-conscious or already concerned about their health were overrepresented. In addition, the dataset did not include information on some key lifestyle factors such as diet, salt intake, physical activity, or stress levels, all of which can influence blood pressure.

Despite these limitations, the study offers valuable insights into the burden of hypertension in a specific region of Sri Lanka. It provides evidence that can support future planning of health services and public education campaigns in similar communities.

To reduce the impact of hypertension, it is essential to strengthen primary healthcare services with a focus on early detection and consistent follow-up. Health workers must be equipped to check blood pressure regularly, educate patients, and offer ongoing support. Community-based programs can play an important role in promoting healthier lifestyles through education and outreach. Public health campaigns should emphasize the importance of maintaining a healthy weight, staying physically active, managing stress, and limiting alcohol consumption.

Conclusion

The findings of the study show that a significant portion of the adult population is living with hypertension, often without knowing it. By investing in community screening programs and prioritizing early intervention, Sri Lanka can take meaningful steps toward controlling this silent but deadly condition. Encouraging regular check-ups and lifestyle changes will not only improve individual health but also ease the growing burden on the national healthcare system.

Selected References

Jayatissa, R., Santos, J. A., Rannan-Eliya, R. P., Trieu, K., Perera, A. G., De Alwis, N., Ranasingha, S., Jayawardana, R., & De Silva, K. H. (2021). A method to monitor the national salt reduction efforts in Sri Lanka and status of salt, potassium and iodine intake in an adult Sri Lankan community. *Journal of the National Science Foundation of Sri Lanka, 49*(1), 111–122. https://doi.org/10.4038/jnsfsr.v49i1.10057

Katulanda, P., Ranasinghe, P., Jayawardena, R., Constantine, G. R., Rezvi Sheriff, M. H., & Matthews, D. R. (2014). The prevalence, predictors and associations of hypertension in Sri Lanka: A cross-sectional population-based national survey. *Clinical and Experimental Hypertension, 36*(7), 484–491. https://doi.org/10.3109/10641963.2013.863321

Rannan-Eliya, R. P., Wijemunige, N., Perera, P., Kapuge, Y., Gunawardana, N., Sigera, C., Herath, H. M. M., Perera, B., Gamage, A., Weerawardena, N., Sivagnanam, I., & SLHAS Collaborators. (2022). Prevalence and associations of hypertension in Sri Lankan adults: Estimates from the SLHAS 2018–19 survey using JNC7 and ACC/AHA 2017 guidelines. *Global Heart, 17*(1), 50. https://doi.org/10.5334/gh.1135

Thesis reference

Amarasingha, A.M.C.J. (2024). Proportion and factors associated with hypertension among participants of the primary health care strengthening project: Divisional Hospital Polgahawela, Sri Lanka. M.Sc. Thesis, Postgraduate Institute of Science, University of Peradeniya

Institutions where research was carried out

Divisional Hospital
Polgahawela

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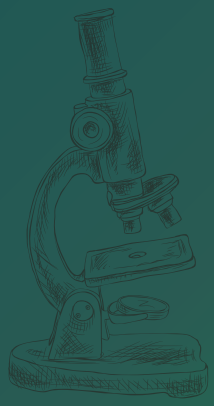

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