(Annexure-I)

Abstract

Municipal Solid Waste (MSW) management is a critical environmental challenge, with legacy waste contributing to greenhouse gas emissions, leachate production, and soil contamination. This study explores the stabilization of **Municipal Solid Waste Fines (MSWF)** using **biopolymers such as Xanthan Gum (XG) and Agar Gum (AG)** as eco-friendly alternatives to lime and cement. The research assesses the impact of biopolymers on **geotechnical properties, long-term durability, and environmental sustainability** of MSWF for civil engineering applications.

MSWF samples were collected from various depths of a legacy waste dumpsite and tested for **Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), specific gravity, and structural stability** after biopolymer treatment. The study found that **UCS increased by 2419% with AG (reaching 3654.88 kPa), cohesion improved by 492.7%, and long-term stability was maintained** beyond 90 days. Biopolymer-treated MSWF exhibited **enhanced compaction properties and reduced leachability of heavy metals**, making it a promising construction material.

Environmental analysis showed that **lime stabilization emitted 102 kg CO2e per ton, while XG emitted 17.76 kg CO2e, and AG was carbon-negative at -2.53 kg CO2e per ton**, demonstrating significant sustainability benefits. Optimized pavement design using **biopolymer-treated MSWF reduced bituminous layer thickness by 25.7%**, leading to material savings and improved performance.

This study establishes **biopolymer stabilization as a viable, durable, and environmentally sustainable solution** for MSWF treatment. The findings highlight **the potential of biopolymers in circular economy applications**, offering a sustainable alternative for waste utilization in geotechnical engineering.

(Annexure-II)

List of Publications form thesis

Journals (Published)

- **Verma, A. K.**, Prasad, A., & Bonal, N. S. (2024). Geotechnical performance of municipal solid waste fines stabilized with xanthan gum and agar gum. *Journal of Material Cycles and Waste Management*. https://doi.org/10.1007/s10163-024-01993-9
  - **IF: 3.2**
- **Verma, A. K.**, Prasad, A., & Bonal, N. (2023). Investigation of the long-term shear strength behavior of municipal solid waste fines stabilized with biopolymer: An experimental study. *Journal of Environmental Chemical Engineering*, 11(2), 109805. https://doi.org/10.1016/j.jece.2023.109805
  - **IF: 7.4 Q1**

Chapters/ Conferences (Published)

- **Verma, A. K.**, Kumar, A., & Prasad, A. (2023). The viability of using biopolymer-stabilized municipal solid waste fines in subgrade to enhance pavement performance. http://dx.doi.org/10.1201/9781003299127-394
- **Verma, A. K.**, Kumar, A., & Prasad, A. (2023). RSM-based optimization of biopolymer-composite for enhancing the mechanical strength of MSW fines. *Indian Geotechnical Conference 2023*.
- **Verma, A. K.**, Kumar, A., & Prasad, A. (2023). An integrated approach to waste management for water resource protection in Uttar Pradesh. *Poster, UPGWC 2023 Sustainable Groundwater Management and Future Challenges*. http://dx.doi.org/10.13140/RG.2.2.12106.75202

Award

- ***Best Paper Award in DRDO Infra Symposium 2024***
  Verma, A. K., & Prasad, A. (2024). A study on alternative low-emission sustainable soil stabilization techniques in general and combat military operations. *Preprint*. https://doi.org/10.32388/sfl54g

In Communication

- **Verma, A. K.**, Singh, S., & Prasad, A. (2022). Slope safety risk analysis of the embankments made of different landfill-mined waste. *Preprint*. http://dx.doi.org/10.20944/preprints202207.0444.v2
- **Verma, A. K.**, Prasad, A., & Bonal, N. S. (2024). Geotechnical Assessment and Sustainable Engineering of Legacy Waste Fines in Riverbank Dumpsites for Pavement Subgrade Construction: An In-Depth Study, Waste and Resource Management (Proceedings of the ICE)

(Annexure-III)

Other collaborative work during PhD

- Dhriyan, S.S., **Verma, A.K**. and Prasad, A. 2025. Evaluating the potential of bio-cementing pond ash using Microbially Induced Calcite Precipitation (MICP). *Construction and Building Materials* 467, p. 140232. https://doi.org/10.1016/j.conbuildmat.2025.140232
- Singh, S., & Prasad, A., **Verma, A. K.**, (2024). Experimental study on bio-cementation of red mud through microbially induced calcite precipitation. *Indian Geotechnical Journal*. https://doi.org/10.1007/s40098-024-00975-w
- Bonal, N. S., Prasad, A., & **Verma, A. K.** (2022). Effect of thermogelation biopolymers on geotechnical properties of red mud tailings exposed to freeze and thaw. *Journal of Cold Regions Engineering*. https://doi.org/10.1061/(ASCE)CR.1943-5495.0000281
- Bonal, N. S., Prasad, A., & **Verma, A. K.** (2021). Effect of microbial biopolymers on mechanical properties of bauxite residue. *KSCE Journal of Civil Engineering*, 25(4), 1297-1311. https://doi.org/10.1007/s12205-021-1297-x
- Kumar, S., **Verma, A.K.**, Prasad, A. (2021). Potential Application of Treated Bauxite Residue. In: Patel, S., Solanki, C.H., Reddy, K.R., Shukla, S.K. (eds) Proceedings of the Indian Geotechnical Conference 2019 . Lecture Notes in Civil Engineering, vol 134. Springer, Singapore. https://doi.org/10.1007/978-981-33-6370-0_13
- **Verma, A.K.,** Mohanty, S. (2021). Finite Element Analysis of Foundation on Layered and Homogeneous Soil Deposit Under Dynamic Loading. In: Latha Gali, M., Raghuveer Rao, P. (eds) Geohazards. Lecture Notes in Civil Engineering, vol 86. Springer, Singapore. https://doi.org/10.1007/978-981-15-6233-4_34
- Bonal, N. S., Prasad, A., & **Verma, A. K.** (2020). Use of biopolymers to enhance the geotechnical properties of coal mine overburden waste. *Géotechnique Letters*, 10(1), 9-18. https://doi.org/10.1680/jgele.19.00071

(Annexure-IV)

About the Author

Mr. Abhay Kumar Verma is a skilled researcher and consultant with expertise in Geo-Environmental Engineering, Waste Management, and Environmental Sustainability. He completing his Ph.D. at IIT (BHU) Varanasi, where his research focused on the sustainable stabilization of municipal solid waste fines (MSWF) using biopolymers. Mr. Verma has contributed to both academia and industry, publishing in leading journals and presenting at international conferences.

Currently, Mr. Verma serves as a Consultant at KPMG India, where he leads sustainability initiatives, ensuring compliance with environmental regulations and developing innovative waste management strategies under Swachh Bharat Mission across urban local bodies of utter pradesh. His work spans a variety of fields, including climate adaptation, circular economy, and soil stabilization, with a strong emphasis on integrating academic research with practical applications to promote sustainable development.

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