



Legacy Waste Site Remediation In Gorakhpur City: Environmental Implications And A Pathway To Green Credits

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Abstract:

India's population expansion and urbanization have created a huge solid waste management problem, with legacy dumpsites continuing to be a major cause of pollution and environmental damage. This study focuses on the thorough remediation of the Ekla Bandha legacy site in Gorakhpur, where biomining was used to methodically treat 1,96,000 MT of legacy waste. The study demonstrates how a hazardous dumpsite has been converted into a green urban asset through resource recovery and sustainable approaches, such as turning excavated materials into useable resources. The study examines the remediation operations' effects on the environment, society, and economy, noting major reductions in methane emissions, enhanced soil and water quality, and the establishment of an urban forest with 50,000 planted trees. It also presents a conceptual framework for coordinating waste rehabilitation efforts with India's Green Credit Program, a groundbreaking program that was introduced in 2023 to encourage environmental sustainability. Gorakhpur exemplifies how cities may combine economic incentives and climate action by utilizing green credits for initiatives like solid waste management and afforestation. By reintegrating waste stream outputs into value chains, Gorakhpur is positioned as a leader in the shift to a circular economy, which lessens reliance on new resources. The study emphasizes the value of community involvement, public-private partnerships, and scalable approaches for other cities dealing with legacy waste issues. This study provides a reproducible methodology for attaining sustainable urban development, increasing India's net-zero promises, and building resilience in urban ecosystems by coordinating remediation with the Green Credit Program.

Index Terms – dumpsite, remediation, bio-mining, green credit, circular economy, sustainability, plantation.

INTRODUCTION

The ever-growing population and rapid urbanisation aimed towards making India a developed nation by 2025, have led India to face major challenges of solid waste management. The country produces 62 million tonnes of solid waste every year and approximately 70% of this waste ends up at dumpsites near the peripheries of the cities contributing to pollution (Meena *et al.*, 2023). India alone has 3159 uncontrolled dumpsites (Chandrappa *et al.*, 2024) thus posing not only a global environmental challenge but also a serious threat to the wellbeing of its citizens. The historical industrial practices and lack of awareness of implications of disposal and management of solid wastes has led to invaluable urban land being turned into heaps of waste called legacy waste dumpsites (Singh *et al.*, 2024). These legacy waste sites impact the air, soil and water quality leading to an overall negative impact on the public health. Heavy metals such as Cadmium, Iron and Lead (Aluko *et al.*, 2024; Gyabaah *et al.*, 2023) exceed the threshold limits at these urban dumpsites and the contamination levels of these heavy metals often range from moderate to extremely polluted as calculated under the geo-accumulation index (Aluko *et al.*, 2024; Aralu *et al.*, 2024). They affect the soil quality of the region particularly due to the process of leaching (Rybalova *et al.*, 2024). The pollutants leach through the soil impacting the water quality (Deonarine *et al.*, 2023; Sanga *et al.*, 2023; Alao *et al.*, 2023). Additionally, accumulation of all types of unsegregated waste gives airborne microorganisms a favorable environment so

much so that they exceed the safety limits leading to bioaerosol contamination causing respiratory issues and disease outbreaks in the nearby communities (Akpeimeh, 2019). Due to accumulation of piles of unsegregated waste their decomposition leads to production of Methane gas which is approximately 20% of global anthropogenic methane emissions (Kumar et al., 2020). The emission of GHGs from these sites poses severe risks not only to ecosystems and public health but also contribute to climate change and environmental degradation (Mor et al., 2023; Ghosh et al., 2023). These urban dumpsites emit a foul stench further degrading the aesthetic value of the area and pose complex risks to public health. Studies have suggested that public residing in the vicinity of 30 m of these dumpsites are more prone to diseases like malaria and dysentery (Nasir et al., 2024) thus indicating a direct correlation between incidence of health problems and distance from dumpsites. Therefore, it has become imperative to address the issue of these dumpsites especially in the rapidly urbanizing areas and regulatory bodies are striving hard to overcome these challenges.

As India strives to mark its impact globally and work towards the global goal of sustainability India has aced its efforts towards waste management with the introduction of Solid Waste Management Rules 2016. These rules are a guide to Urban local bodies, waste generators and other stakeholders towards managing their municipal solid waste and remediating the years built legacy waste dumpsites. Major cities like Delhi and Mumbai are transitioning from open dumps to engineered landfills, with projects focusing on waste excavation, sorting, and composting (Rodic-Wiersma & Gupta, 2012) and many other cities are working on waste to energy models creating Refuse- derived fuel from combustible fractions. In addition to reducing environmental risks, remediation of these sites offers chances to reclaim land and use it for more economically viable and sustainable uses.

Under this framework efforts towards waste management are gaining pace but effective implementation is still significantly hampered by issues such as illiteracy, a lack of awareness, and poor infrastructure. Zakhilwal et al, 2024 in their research concluded that the infrastructure required for waste management, including effective collection systems and treatment facilities, is lacking in many Indian cities. Additionally, waste generation has increased manifold due to growing urbanization and is expected to increase more, surpassing the capacity of appropriate disposal techniques (Dutta et al., 2020). Certain cities, like Gadag, with already developed infrastructure, have a strong foundation to build upon. However, enhancing waste management systems further will ensure they can effectively address the anticipated waste generation of the coming decade (Arunkumar et al., 2024). India also faces a challenge of lack of awareness for proper waste segregation and disposal practices (Arunkumar et al., 2024) and poor community engagement. Therefore, educational interventions like mass awareness programs, street plays, door to door awareness are crucial to address the gap between willingness to participate in waste management practices and the lack of knowledge and skill to do it (Singh et al., 2024). Studies suggest that most of the municipal solid waste in India (20-30 %) is managed by informal waste pickers (Suvarna, 2024; Baker, 2024), significantly alleviating the burden on formal waste management systems. But historical neglect and exclusion from decision-making processes has contributed to the widespread mistrust that exists between informal waste pickers and municipal authorities (Pastor et al., 2024). Formal waste management regulations and the realities encountered by waste pickers are significantly out of sync, which prevents them from receiving necessary services like door-to-

door waste collection. (Pastor et al., 2024). Thus, there is a critical need of laws that incorporate unofficial recyclers into official waste management systems in order to improve sustainability and efficiency.



Figure 1. Administrative map of Gorakhpur Nagar Nigam

Gorakhpur is the northernmost district of Eastern Uttar Pradesh and is located in the latitudes of $26^{\circ}13' N$ and $27^{\circ}29' N$ and longitudes of $83^{\circ}05' E$ and $83^{\circ}5' E$. The city has a population of 9,65,777 in the 2011 census and is divided into 5 administrative zones and 80 wards spanning an area of 220 square kilometers, as shown in Figure 1. Recently the city got a geographical indicator tag for centuries old traditional art form-Terracotta work. A prominent religious structure, the Gorakhnath Math, is also located in the city making the city culturally and religiously significant. But as the nation progresses towards development and urbanisation, the city faces urban and environmental challenges. Amongst these the management of solid waste posed a great challenge for the authorities. The per capita generation of MSW in Gorakhpur is approximately 434.5 TPD which is expected to rise to 625 TPD by the year 2040 according to CPHEEO manual and SBM guidelines. Since times immemorial the mismanaged waste of the city was dumped at a site called the Ekla Bandha, near Nausarh, and in proximity with the river Rapti. Recognizing the need to remediate the site Municipal Corporation took over the challenging task in May 2022.

OBJECTIVES

- To investigate the potential contribution of legacy waste site cleanup to the acquisition of green credits.
- To put out a conceptual framework that links eligibility for green credit to remediation efforts.
- To investigate the shift from a linear to a circular economy.

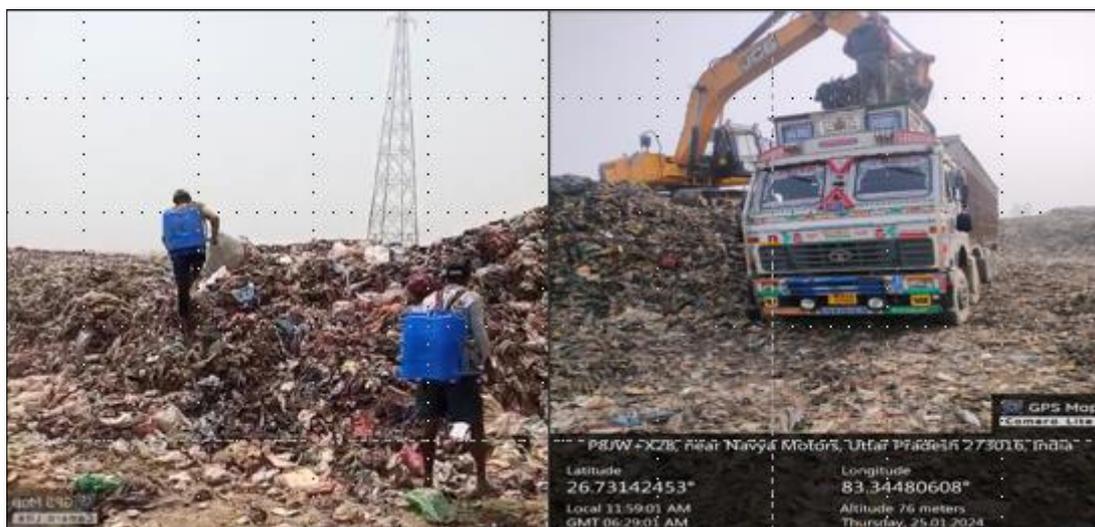
Case Study: Gorakhpur Municipal Corporation

The city of Gorakhpur has emerged as an example for environmentally responsible living and efficient management of waste. India's net zero ambition has prompted Gorakhpur city to participate in the Green Credit Program which was introduced in October 2023 in India. Green credits are basically incentive units that are assigned to a specific environmental initiative and can be earned by contributing to environmental initiatives and sustainable development. These credits can be validated and traded on centralized platforms. They use observable and verifiable activities, including afforestation, to encourage adaptation efforts. The Green Credit Program divides green credits into eight major categories: waste management, air pollution reduction, tree planting, water harvesting, sustainable agriculture, ecomark label development, mangrove conservation and restoration, and sustainable building and infrastructure. The authorized administrator for developing the green credit calculating methods and accreditation procedures is the Indian Council of Forest Research and Education (ICFRE). Gorakhpur aims to apply for green credits in the direction of tree plantations and waste management.

The city has adopted contemporary waste management techniques with the unchanging goal of obtaining green credits. These tactics include the remediation of legacy sites, the shift to a circular economy, and the development of a conceptual framework for connecting remediation activities to green credit eligibility. The city's strategies and progress toward achieving these goals are examined in this case study.

Investigating the Potential Contribution of Legacy Site Cleanup to Green Credits

Municipal Corporation Gorakhpur faced a huge challenge of managing 1,96,000 MT of legacy waste that had accumulated at Ekla Bandha dumpsite for decades. This site posed serious public health risks as danger of fire, virus, or bacteria outbreak etc. as well as environmental risks such as leaching, bad air quality, soil pollution, water pollution etc. The site is less than 50 m away from the river Rapti that flows through the



city. To address this issue the Municipal Corporation undertook remediation of the site with the technique of biomining (Mohan et al., 2020).

Figure 2 & 3: During the process of remediation.

Through this process, legacy waste was systematically excavated, segregated, and treated, achieving 100% remediation.



Figure 4, 5 & 6: During and after the remediation.

After excavating and segregating various types of waste i.e., soil, refuse-derived fuel, recyclables, and inert materials they were put for various uses as mentioned in the table 1.1 thus entering it back into the loop of consumption.

Table 1: Description of mined materials

MATERIAL	QUANTITY	USE
Soil recovery	Approx. 1,56,800MT	Used in low-lying land filling and agriculture
RDF	Approx. 15,680 MT	Sent to cement manufacturing plants.
C&D waste	Approx. 19,600 MT	Sent to the C&D plant at Mahesra
Other materials like glass and plastics	Approx. 3,920 MT	Sent for recycling and a revenue of Rs 50000 was earned.

After the remediation the site is currently being developed into a dense forest and 50,000 plants have been planted on the site. The trees are supposed to blossom well in the upcoming 10 years, thus sequestering equivalent carbon of the city.



Figure 7 & 8: After remediation pictures

Further, post remediation, surveys were conducted, and water and air samples were tested by Enviro-Tech Services against various parameters the results of which are given in Figures 9 & 10. The results suggest that values for PM10 and PM 2.5 are well below the permissible limits of 100 ug/m³ and 60 ug/m³ as per CPCB standards. The values for SOX and NOX were 14.2 and 33.7 ug/m³ which were again well below the threshold limit of 80 ug/m³. Groundwater samples were also analysed for various critical parameters of Colour, Turbidity, Total Dissolved Solids (TDS), Alkalinity, Total Hardness (CaCo₃), Chloride (Cl), Calcium (Ca), Sulphate (SO₄), Fluoride & Chlorine and all of these tested parameters were well below the standards of Bureau of Indian Standards (BIS) IS 10500:2012.

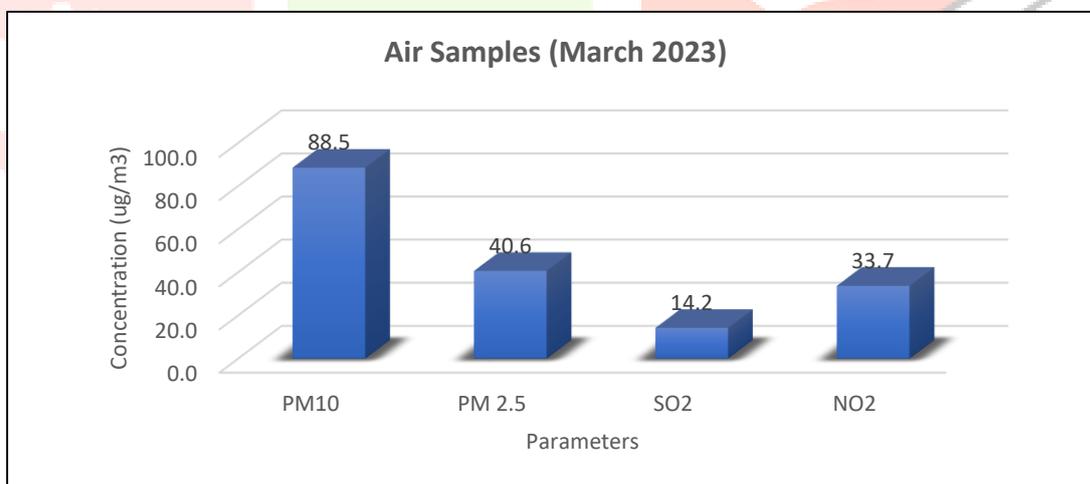
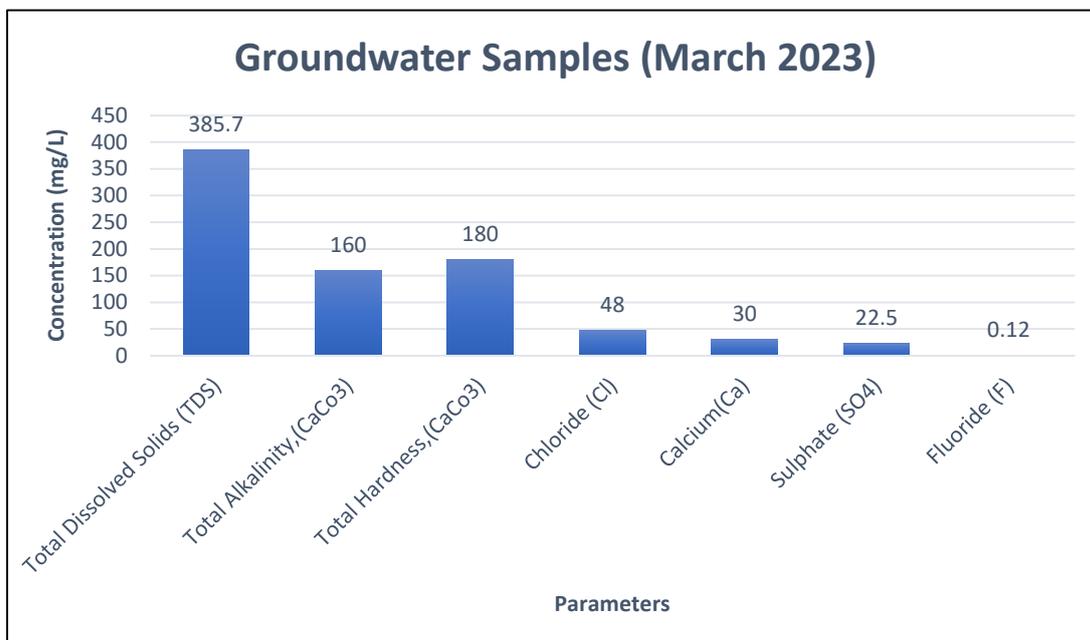


Figure 9: The graphical results of air samples post remediation.**Figure 10:** The graphical results of groundwater samples post remediation.**Figure 11:** Plantations at the remediated site.

Thus, the biomining of the legacy site at Ekla Bandha helped to improve the PM-10 levels of the city. The city has also participated in Vayu Survekshan 2024 where it achieved 4th rank all over India. The city showed more than 60% reductions from the base year. Subsequently, the methane emissions and leachate pollution from the dumpsite also got remediated. The land is now being used to develop an urban forest and 50000 trees have already been planted in this direction.

Establishing A Conceptual Framework Linking Green Credit Eligibility to Remediation Efforts

Gorakhpur has developed an operational framework to assess its eligibility for green credits through waste remediation efforts. The framework includes the following key elements:

- **Remediation Metrics:** Tracking waste segregation efficiency, material recovery rates, and emissions reductions.
- **Certification and Validation:** Collaborating with accredited organizations for third party verification to validate remediation outcomes.
- **Economic Valuation:** Estimating cost savings from avoided landfill expansion and potential revenue from green credits with the help of Ministry of Environment, forests and Climate Change, ICFRE being the nodal agency for the Green Credit Program.
- **Community Engagement:** Ensuring stakeholder participation to build public trust and enhance transparency.
- This framework thus positions Gorakhpur as a pioneer in integrating waste remediation into green credit systems, creating pathways for other cities to replicate.

Transitioning From a Linear to a Circular Economy

A paradigm change in waste management is demonstrated by Gorakhpur's adoption of a circular economy approach. The infrastructure developed in the city makes it possible to handle all waste streams thoroughly, guaranteeing that resources are recycled, reused, or repurposed. There is maximum recovery of resources thereby reducing the stress on fresh resources and reducing waste generation. Output from one waste stream acts as input for another, exemplified using processed C&D waste in construction projects. there is also a strict emphasis on public-private partnerships for developing efficient technologies and training stakeholders. This closed-loop technology minimizes the environmental impact and helps conserve the local resources.

Solid Waste Management Infrastructure of Gorakhpur

Gorakhpur has established a robust waste processing infrastructure to transform waste into resources, fostering a circular economy:

- a. Wet Waste Management: the city produces 239.5 TPD of wet waste. The waste is collected by CNG vehicles and taken to composting facilities. There are 12 compost pits out of which 9 compost pits have a capacity of 15 TPD, 1 compost pit with a capacity of 20 TPD and the remaining two have a capacity of 30 TPD each as shown in Figures 12, 13 & 14. This compost is utilised by the horticulture department and used further for agricultural purposes.



Figure 12, 13 & 14: Photographic evidences of Compost pits.

- b. Dry Waste Management: The total dry waste generation in the city is 173.8 TPD which is collected by the Municipal Corporation in CNG fuelled vehicles and taken to material recovery facilities (Figure 15 & 16) where the segregated waste is processed and sold to relevant industries.



Figure 15 & 16: Photographic evidences of MRF's.

- c. Construction and Demolition Waste: Gorakhpur ULB has a 50 TPD C&D Waste processing plant at Mahesra where almost 45 TPD of waste is processed and the outputs are sold to construction companies and local builders. Figures 17,18 & 19 depict the details of the plant. The pavement blocks that are made at the plant are being utilised by the ULB itself for pavement of roads under NCAP scheme.

CONCLUSION

The successful restoration of the Ekla Bandha legacy waste site in Gorakhpur serves as proof of how creative waste management techniques may spur social, economic, and environmental change. In addition to removing a significant cause of environmental deterioration, Gorakhpur's adoption of biomining and shift to a circular economy framework has opened the possibility of recovering priceless urban space for sustainable uses. The study demonstrates how waste disposal, urban planning, and public health are interrelated and may work together to produce a more sustainable and healthier urban environment. It can be concluded that the



cleanup will have a positive impact on methane emission reductions and the local soil and water quality. The afforestation project under which 50,000 trees have been planted is suggested to create a green urban area in the coming years.

Figure 17, 18 & 19: C&D Plant at Mahesra

The project's relevance is further enhanced by its integration with India's Green Credit Program. The Green Credit Program, which was first introduced in 2023, assigns tradable credits for environmental actions like pollution reduction, waste management, and afforestation. Gorakhpur is an example of a city that can profit from environmental advancements and support India's net-zero carbon goals by incorporating the results of legacy waste treatment into the program. A total of 1.96 MT of legacy waste was bio mined and the resulting resource recovery is an example of a circular economy, which reintegrates waste-derived fuel, soil, and recyclables into economic value chains. This strategy not only reduces the negative effects on the environment but also creates economic benefit, making Gorakhpur a leader in the use of waste as a resource. The project also emphasizes how crucial public-private partnerships and community involvement are to attaining sustainable urban development. Involving a variety of stakeholders, including local communities, private companies, and municipal corporation has been essential to the project's success and the development of a sense of shared responsibility. This cooperative model acts as a guide for other cities dealing with comparable issues, especially in a country like India that is urbanizing rapidly.

Cities across the nation are struggling with legacy waste, and Gorakhpur's project provides insightful information on how to approach these issues comprehensively. Gorakhpur has made it possible for towns to reduce environmental concerns and obtain real financial benefits by tying waste cleanup to the Green Credit Program. With this integration, waste is now acting as a resource, signaling a paradigm shift in urban administration. A future where urban growth and environmental care coexist together is being inspired by Gorakhpur's persistent efforts in waste management, afforestation, and community-driven projects.

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