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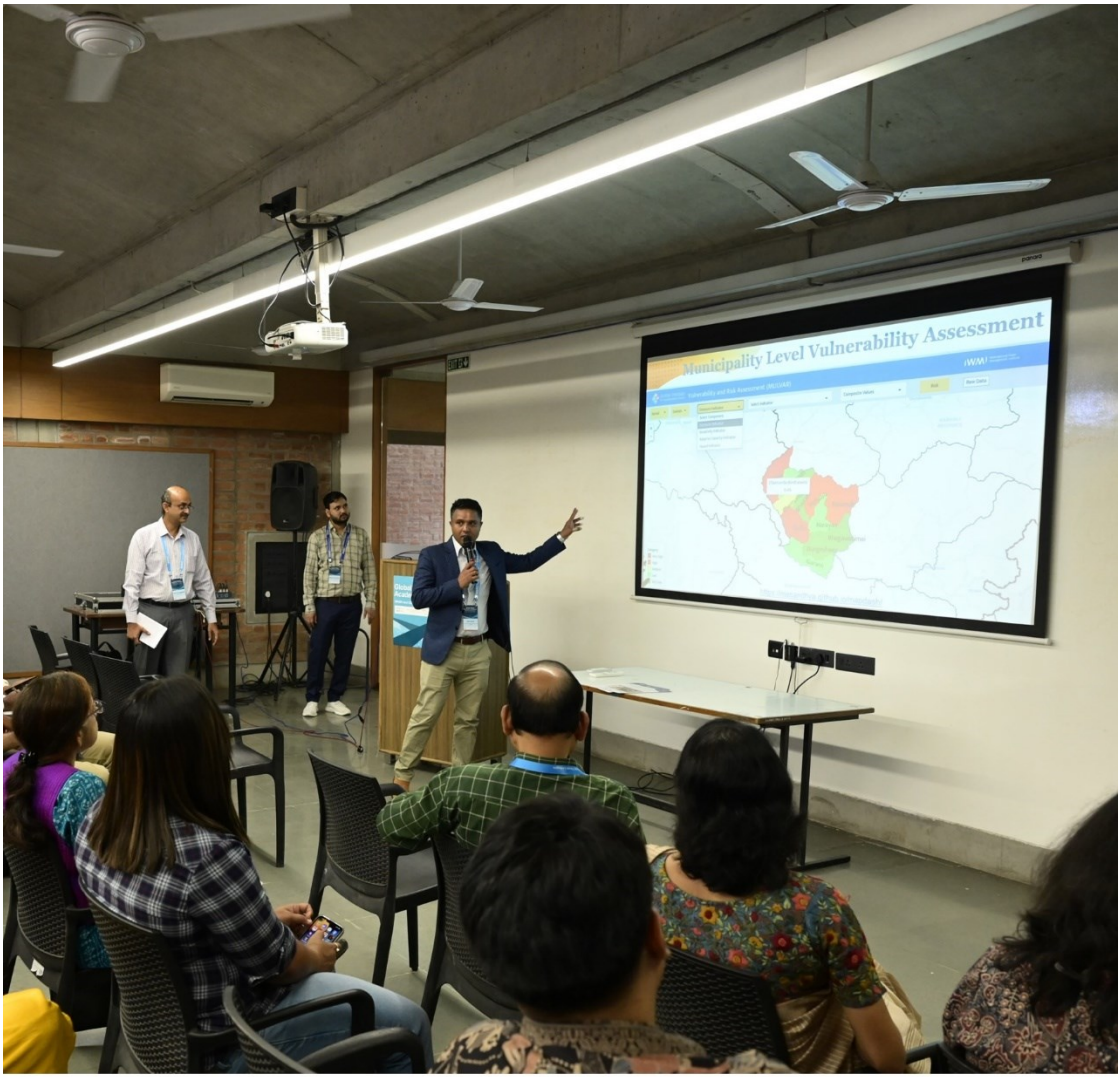

Verbal Presentations Abstracts

Theme 1.1: Monitoring WASH Outcomes

Changing Climate Impacts on Small Town WASH - A local perspective of Chintamani

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Chintamani, a small town with a population of approximately 92,802, is situated 80 km from Bengaluru in a water-stressed region. Chintamani faces frequent droughts, with an average annual rainfall of about 700mm. A 40-year analysis of rainfall data shows a 20% reduction in annual mean minimum rainfall. According to the District Disaster Management Plan Chintamani has experienced drought in 13 of the past 16 years.(DDMA, 2024) A stark reminder of its ongoing battle with water scarcity. With no perennial water sources, the town relies heavily on groundwater, leading to over exploitation. (Board, 2023) This study aims to assess the preparedness of small towns in India for climate change impacts, using Chintamani as a case study to understand the impact of climate change in the water, sanitation, and solid waste management sectors. A mixed-methods approach was employed, combining quantitative household surveys (in 520 households) —conducted in collaboration with TIDE and supported by BMZ—with qualitative data gathered through focused group discussions and semi-structured interviews in vulnerable communities, particularly slum areas. This comprehensive methodology provided insights into the challenges faced by residents and the perspectives of local government officials regarding WASH service delivery. Findings reveal that Chintamani's water crisis is worsening.

The town has more than 150 borewells, yet only 87 remain operational, pumping water almost 24/7. Despite this relentless effort water supply fluctuates from 40 to 75 lpcd, with frequencies varying from twice a week to once every 10 days in extreme conditions. During summer, about 34% of operational borewells run dry, exacerbating water shortages. Surface water sources, which accountust 20% of the town's demand, is equally unsustainable, with water levels reaching dead storage by October 2024, much before the start of dry season (February to June). This situation has fuelled a rise in the private water tanker business, as residents struggle to cope. Our survey reveals that during drought years, 94% of respondents rely on tanker water, with the cost of a 5000-litter tanker skyrocketing to Rs.1000 - Rs. 2000, compared to Rs. 500 during normal periods. This growing dependence on expensive tanker services underscores the severity of the town's water crisis.The water crisis is also impacting the town's sanitation infrastructure. Reduced water availability has led to chocking of sewer lines due to the absence of minimum flow velocity (0.3-0.6 m/s), thus resulting in increased complaints of sewer blockages during drought periods, with municipal records showing nearly double the number of complaints compared to non-drought seasons. The situation is dire in Chintamani's 17 notified and 8 informal settlements, where over 20% of the population resides. Around 95% of slum dwellers rely on costly private tankers during droughts, increasing their financial burden. Poorly maintained sanitation systems, combined with water shortages, force many to resort to open defecation, with community toilets often falling into disrepair.

Solid waste management is a major challenge in Chintamani, contributing significantly to GHG emissions. SWM accounts for 67% of WASH-related emissions in Chintamani, with the town generating about 30TPD. Most of this waste remains unprocessed and is dumped at the site. As operations at the waste processing site struggle, this

ongoing accumulation of legacy waste harms the environment and directly impacts residents' health and well-being. Through this study we observe a stark difference between a small town and a big city is their adaptive capacity. Bengaluru's 2024 water crisis, for example, showcased the city's ability to respond effectively due to its technical expertise, political will, financial resources, and active civic engagement. In stark contrast, Chintamani tells a very different story. With limited resources, constrained capacity, and underdeveloped infrastructure., Chintamani struggles to adapt in the same way that larger cities like Bengaluru can. The town's ability to manage crisis is hampered by the multiple challenges stated above, making it far more vulnerable to water shortages and other climatic impacts.

The study points out that while small towns may contribute minimally to climate change, they are disproportionately vulnerable to its consequences. Integrating climate measures into WASH planning instruments is a step forward in tackling growing climate challenges. This will provide an opportunity for small towns to understand climate threats and adopt strategies while they gradually improve infrastructure. Further, addressing climate change impacts in small towns requires a collaborative approach involving government departments, local communities, and NGOs. Integrating local knowledge into climate strategies will foster more effective solutions. While existing frameworks at national and international levels provide some guidance, they often overlook the specific needs of small towns like Chintamani. This research underscores the necessity for a ground-up framework that can guide structured climate preparedness and resilience planning tailored to diverse small-town contexts across India.

Tech-Enabled Governance: Scaling Inclusive and Sustainable Water Ecosystems through the Jal Jeevan Mission in Assam

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Technological advancements are reshaping the way societies address complex challenges, driving progress toward a more sustainable and equitable future. In the realm of water services, innovations in digital systems and participatory governance are enabling transformative changes, creating resilient and inclusive solutions for communities. The Jal Jeevan Mission (JJM) exemplifies this shift, with its ambitious goal of ensuring universal access to safe and reliable water in rural India.

In Assam, JJM's implementation showcases the seamless integration of technology and community-driven governance to build resilience in water service delivery. Under a robust operations and maintenance framework, technology serves as an enabler, incorporating IoT-based monitoring, real-time grievance redressal mechanisms, groundwater recharge initiatives, and lithological profiling to ensure sustainability. By balancing technological interventions with human-centric approaches, JJM envisions empowering end-users, particularly through Water User Committees (WUCs), to take ownership of water management, fostering accountability, transparency, and inclusivity in the process.

This paper draws insights from global service delivery models in the water ecosystem to build the learning curve while spotlighting the JJM interventions in Assam. These initiatives demonstrate their significant role in enhancing systemic resilience through optimized resource utilization, technological integration, and capacity building. By fostering transparency and inclusivity, they not only improve access to water resources and enhance quality of life but also offer a scalable model for resilient governance in public service delivery. The technology lever, rather than serving as a standalone solution, acts as a powerful catalyst for systemic change—empowering communities to take ownership of water governance and strengthening operational ecosystems. Aligned with long-term sustainability goals, this integrated approach promises a healthier and more sustainable future for all rural households.

Intersectoral collaboration for the implementation of localized, climate-resilient WASH strategies in Karnataka: A research proposal

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Intersectoral collaboration for the implementation of localized, climate-resilient WASH strategies in Karnataka: A research proposal (Mohith Gowda DM, Ashish Shetty, Shraddha Shrivastava) Despite significant investments in Water, Sanitation, and Hygiene (WASH) infrastructure, challenges persist in achieving universal access and ensuring the sustainability of services. The implementation of effective and sustainable WASH systems requires a holistic, intersectoral approach. The key sectors include Rural Development and Panchayat Raj, Health, and Water and Sanitation. While health, sanitation, and local governance are all State subjects, siloed governance models often fall short of addressing local needs, particularly in the context of climate change and socioeconomic disparities.

This research aims to explore how an intersectoral framework can enhance the implementation of localized, climate-resilient WASH strategies, focusing on the state of Karnataka, India. This study proposes to assess the current state of WASH implementation in Karnataka including WASH infrastructure, service delivery mechanisms, and policy frameworks with the perspective of understanding the role of different departments (envisioned versus current). This will also include assessing the impact of Climate Change on WASH systems, which makes intersectoral coordination critical. The next step would be to identify intersectoral gaps in terms of coordination and collaboration between key departments (Rural Development and Panchayat Raj, Health, and Water and Sanitation, Kalyana Karnataka Development Board) for WASH implementation. With this information at hand, an intersectoral framework will be designed for effective collaboration, including mechanisms for resource allocation, decision-making, clear distinction of roles and responsibilities and monitoring and evaluation.

A mixed-methods approach will be employed to gather both qualitative and quantitative data along with a comprehensive review of literature, including government reports, academic papers, and grey literature, to identify best practices and challenges in intersectoral coordination, especially at the local level. Key policies that will be analyzed include the Swachh Bharat Mission, Jal Jeevan Mission, Comprehensive Primary Healthcare guidelines, Atal Mission for Rejuvenation and Urban Transformation, and other state-specific schemes/guidelines on WASH and related interventions to assess their potential for intersectoral collaboration. These findings will be complemented by key informant interviews with government officials and social enterprises in the WASH space along with focus group discussions with local implementors, field workers, beneficiaries, etc. Surveys and observations will be conducted in focus districts to assess the availability, accessibility, and quality of WASH services at the community level.

Comparative case studies on the northern and southern regions of Karnataka will be conducted to assess the effectiveness of different WASH interventions in different regional contexts. The research is expected to produce a comprehensive assessment of the current state of WASH implementation in Karnataka, highlighting gaps and

challenges. This will be complemented with a detailed analysis of the intersectoral coordination mechanisms and their effectiveness along with a proposed intersectoral framework for improved WASH governance and service delivery. The study will provide and add to the existing literature by providing recommendations for policy and program interventions to enhance the climate resilience of WASH systems. This research will contribute to the development of evidence-based, context-specific WASH interventions. By promoting intersectoral collaboration, this study aims to strengthen the resilience of WASH systems in the face of climate change and ensure equitable access to safe water and sanitation for all.

Improving the resiliency of WASH systems under climate and social change in the global south

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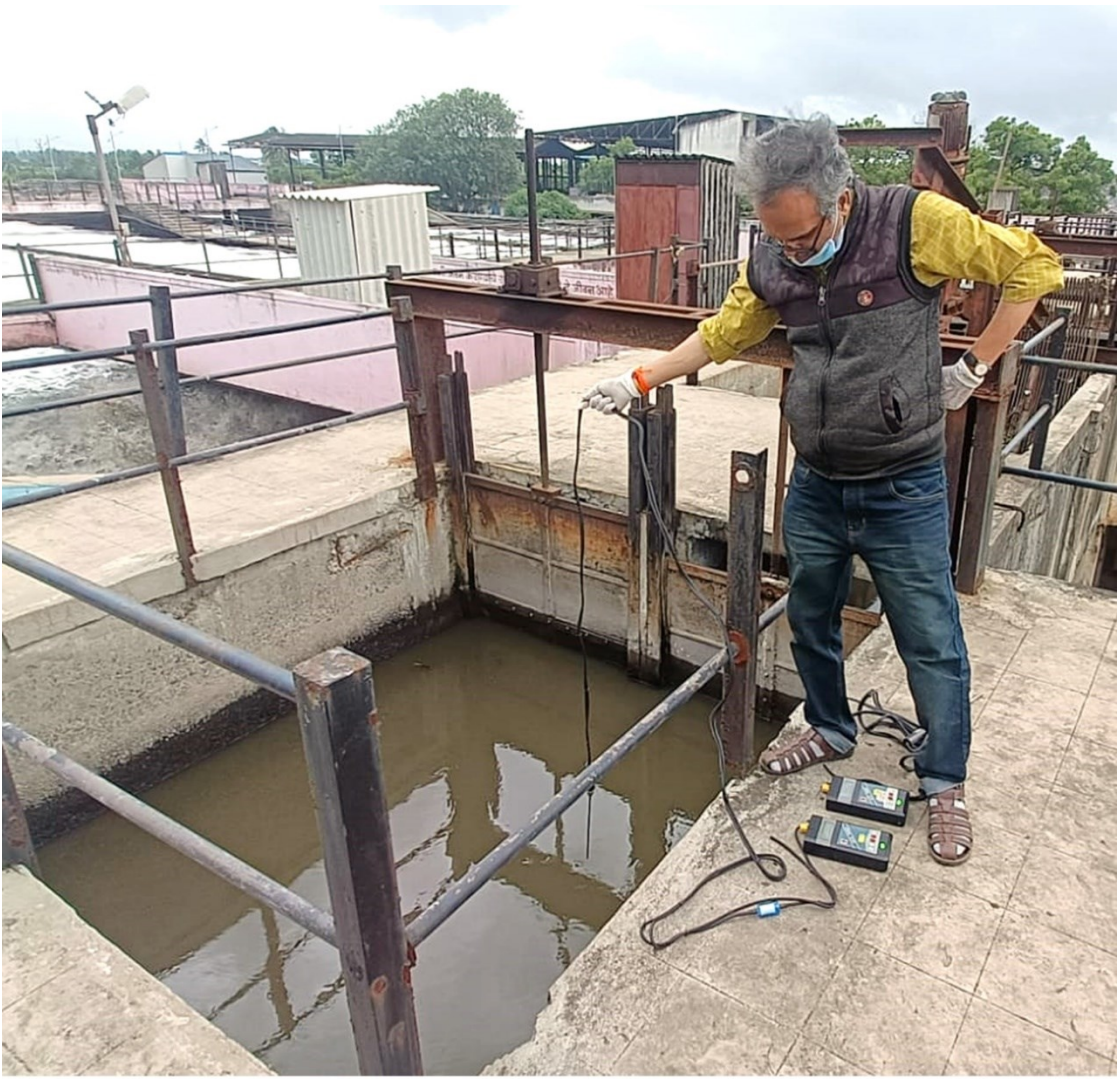
Climate change has significantly impacted water supply sanitation and hygiene (WASH). With the increase in extreme weather events like floods, WASH services have been negatively impacted. For instance, the September 27-28, 2024, flood in Nepal damaged more than 1600 WASH systems resulting in a loss of NPR 3.5B. The loss is because the systems could not resist the impact incurred by the extreme events. Most of the systems in the climate-vulnerable areas of Nepal (for example, Dailekh district in Karnali province and Sarlahi district in Madhesh province which are the study regions for this research) (MoPE, 2019) are not able to resist such kind of extreme events. Further, with the changes in social dynamics such as population growth, migration, social taboos, economic disparities, the WASH systems are more impacted by vulnerable and marginalized groups and making the system less resilient. To address these resiliency gaps in the WASH systems, we developed a framework to make the WASH systems resilient against climate change and social dynamics and make the system inclusive. For this, we considered five domains namely community capital, environment, infrastructure, institutional capacity and governance, and WASH system management. These domains were designed in a participatory manner where WASH stakeholders were invited to draw the relevant questions which were then asked to the water user committee members to map the resiliency. The results show that most of the systems in both districts fall short of improving the institutional capacity and governance that are responsible for making the systems less resilient to climate and social changes. The research concludes that by improving the governance capacity of the local government and the water user committee, the resilience of the system could be improved. The governance and institutional capacity include improving the capacity of system maintenance technicians and coordination between the local government and the water user committee.



Theme 1.2: Monitoring Emissions in WASH

Assessment of Methane Emission from Pit Latrines in Bangladesh Considering Hydrological Variations

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One major source of greenhouse gas (GHG) emissions, especially methane (CH4), is pit latrines and other on-site sanitation systems (OSS). Globally, about 1.6 billion people use pit latrines, particularly in low- and middle-income (LMIC) countries. In Bangladesh, about 62.8% of the population uses pit latrines, highlighting their importance in the country's sanitation infrastructure. However, methane emissions from pit latrines are understudied compared to septic tanks. Methane from pit latrines is generated through anaerobic decomposition of organic matter, a process intensified by groundwater inundation. Seasonal variations in groundwater levels, combined with Bangladesh's susceptibility to flooding, increase methane generation. The use of an average emission factor in the IPCC general formula often overestimates methane emissions. This study combines population and sanitation data with regional changes in groundwater levels to quantify methane emissions from pit latrines in Bangladesh. The study utilized groundwater data for September from the Bangladesh Water Development Board, from 1995 to 2024. Data from 425 observation wells were analyzed using the Inverse Distance Weighted (IDW) interpolation method in QGIS to create a spatial map to identify areas likely to experience groundwater inundation. Depths of three meters for pit latrines were assumed based on literature and field studies. Sanitation system usage data were used from the Bangladesh Multiple Indicator Cluster Survey (MICS) 2019, which provided division-wise percentages of pit latrine use. District-level population density from the Bangladesh Bureau of Statistics was combined to estimate the number of pit latrine users. To determine the methane generation from wet and dry pit latrines, methane correction factors (MCFs) specified by the IPCC were used. A correction factor of 0.7 was used for wet pits, which were inundated by groundwater, whereas a correction factor of 0.1 was used for dry pits. To account for the effect of groundwater on methane production, emissions for dry and wet pits were computed independently. The impacts of seasonal flooding on methane generation were evaluated by a sensitivity analysis that took into account four-month, half-year, and full-year inundations.

Due to variations in groundwater levels across the country, our study found that methane emissions varied significantly throughout Bangladesh. Using the inundation map, high methane-producing locations were identified, such as flood-prone districts like Kurigram and Barisal, as well as coastal regions where pits are frequently submerged by the groundwater table. These areas were contrasted with districts like Dhaka and Rajshahi, where groundwater levels were generally lower, resulting in reduced inundation risks. Annual methane emissions from pit latrines in Bangladesh were estimated at 116.79 kilotons (kt), equivalent to 3,270 kt of CO?, contributing around 1.3% to the country's total GHG emissions. This estimate is significantly lower than the 8,680 kt of CO? calculated using the IPCC general formula in a previous study. The discrepancy highlights the overestimation made by traditional methods that do not account for variation in groundwater inundation. A dramatic increase in methane emissions under longer inundation periods was found by the sensitivity analysis. For example, emissions can rise to

6,129.6 kt CO? when pits are inundated for four months, 7,559.3 kt CO? for six months, and 11,848.5 kt CO? under full-year inundation. These results demonstrate the critical role of hydrological dynamics in methane generation.

The study is highly relevant to Bangladesh's sanitation management initiatives. By providing a more accurate estimate of methane emissions from pit latrines, the results challenge assumptions used in the IPCC average emission factor in previous studies, which often overlooks the variation of local environmental variables. The results help to clarify how groundwater level affects methane emissions and offer guidance for mitigation measures. One practical measure is the timely emptying of pit latrines before the monsoon season. This strategy would minimize prolonged inundation and the associated anaerobic conditions that drive methane production. In flood-prone areas, improving pit latrine designs to prevent groundwater infiltration could reduce emissions. Sanitation solutions without pits, such as eco-toilets or septic tanks, could be promoted in regions with shallow groundwater tables. This study also demonstrates the significance of taking hydrological variation into account when having broader conversations about mitigating climate change and managing sanitation sustainably. By incorporating groundwater level variations in methane emission calculations, this study makes a significant contribution to the field of sanitation-related GHG research. The study shows how important it is to use localized data in improving the accuracy of emission calculation. The study demonstrates that the generalized formula often overestimates emissions in regions like Bangladesh by not considering the local hydrological factors. Accurate GHG estimates are vital for monitoring progress, which makes this study extremely important. Decision-makers can anticipate increased methane-generating locations and take specific measures with the use of the inundation maps created in this study. By coordinating sanitation management practices with local environmental conditions, the research provides a means for reducing methane emissions while ensuring sustainable access to sanitation.

Emerging Trends in WASH Related GHG Emissions Across Small Towns in South Asia

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Home to a quarter of earth's population, South Asia is a region characterised by its significant vulnerability to climate change, facing severe threats from extreme weather events, rising sea levels, and changing monsoon patterns, with millions affected by climate-related disasters over the past two decades. Characterised by an average of 6% GDP growth rate, the South Asian region is one of the fastest developing regions in the world. A big chunk of this development is fuelled by the growth of small and medium towns in India, Nepal, and Bangladesh, which are increasingly becoming hotspots for urban growth. In small towns across South Asia, greenhouse gas (GHG) emissions from the water, sanitation, and hygiene (WASH) sector are becoming an escalating environmental concern that is intricately tied to rapid urbanization, population growth, and infrastructure limitations. Unlike developed nations, where robust infrastructure and regulatory frameworks have led to more controlled emissions, small towns in South Asia face critical gaps in waste and water management. Extreme weather events like floods and cyclones threaten the resilience of water and sewerage systems, disrupting water quality and infrastructure. When WASH services are interrupted, the repercussions are profound: health deteriorates, nutrition suffers, educational access is hindered, and livelihoods are jeopardised, especially for vulnerable communities, who inherently have a limited capacity to deal with such profound changes.

The GHG emissions indicators reflect the quantum of WASH related GHG emissions produced by the various municipal and domestic WASH processes within the defined Urban Local Body boundary. This information would be particularly useful in identifying the most carbon-intensive activities in the town and replacing them with more sustainable and carbon neutral solutions. The carbon footprint of each sub-activity of water, wastewater and solid waste management is calculated against the general carbon accounting guidelines and reported in tCO2e. This would incorporate both direct (Scope 1) and indirect (Scope 2 & 3) emissions. Most GHG emissions tracking systems record emissions of the seven gases currently required for most national GHG inventory reporting under the Kyoto Protocol: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3). In the water sector, electricity consumption is the primary contributor to greenhouse gas emissions.

Groundwater pumping or pumping from a water source such as rivers or water bodies away from the city contributes to significant energy consumption. These emissions are categorised under indirect emissions. Wastewater can be a methane (CH4) source when treated or disposed of anaerobically. It can also be a source of nitrous oxide (N2O) emissions. Greenhouse gas emissions are produced at many phases of the Solid Waste Management value chain, encompassing garbage collection, transportation, treatment, and disposal. This sector includes both primary and secondary emissions. A comprehensive WASH related GHG emissions inventory was developed to account for the major sources of all such emissions. This study was piloted in the 2 Indian towns of Chintamani in Karnataka, Leh in Ladakh, and Kirtipur in Nepal and Savar in Bangladesh, where water, wastewater

and solid waste related emission data was collected from various sources, including municipality documents, operator interviews etc. The towns were thus chosen to represent the various geographies and economies in South Asia, with a cold desert (Leh), a mountain valley (Kirtipur), a plateau (Chintamani) and a flood plain (Savar) included. The study focuses on identifying existing and developing trends in GHG emissions that are present across geographies and economies and will also recommend mitigating actions to best manage said emissions.

Trend 1 – Solid Waste emissions top the chart, Emissions from solid waste, including legacy waste are the highest contributors across all the 4 pilot towns, except for Leh, where the 100,000 MTs of legacy waste was recently remediated. Contributions from legacy waste alone make up about 57% and 48% of total solid waste emissions from Chintamani, India and Savar, Bangladesh respectively.

Trend 2 – Recorded emissions from water and water supply systems are significantly different in Bangladesh and Nepal from India. Savar is a noticeable outlier to the data in two aspects. It is a town completely devoid of municipal water supply. So, it depends on its groundwater sources to fulfil this demand, by employing a mix of shallow and deep tubewells and borewells all of which are privately owned by the households or the community. Subsequently, domestic pumping contributes almost all the water-related emissions which is a departure from the trend as noticed in the other three towns. Kirtipur's water demand is met by a combination of spring water and municipal supply which explains the low emission.

Trend 3 – GHG emissions from WASH range between 20 and 40% of all GHG emissions in the town. Tallying the per capita emissions data from WASH against the average annual per capita emissions figure for each town, we see 4 percentages. Savar has the highest per capita emissions, inspite of being the most populated of the 4 towns. Kirtipur has the lowest population amongst the 4 focus towns, which makes it a high per capita emitter in the WASH sector, followed by Chintamani, and Leh.

Trend 4 – Solid waste and wastewater have higher direct emissions (Scope 1). Water has higher energy consumption (Scope 2) emissions.

A majority of GHG emissions for solid waste and wastewater sector appear in the form of direct emissions of methane during decomposition (for solid waste – legacy waste, dumping ground, composting etc) and treatment (for wastewater). Although there is contribution from grid generated electricity in both sectors, they are negligible in comparison to the direct emissions. The water sector on the other hand has next to nothing direct emissions but the emission contribution from energy requirements are significantly higher and make up almost all of the emissions from the water sector. For the overall sector, direct and indirect emissions are almost equal, with direct emissions only slightly higher than the contribution from grid derived energy emissions.

Beyond Tier 1 Estimations: The Urgent Need for Direct GHG Measurements in WWTPs a case study in Mexico for the global south

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Greenhouse gas (GHG) emissions from wastewater treatment plants (WWTPs) are a growing environmental concern, particularly in developing countries undergoing rapid urbanization and industrialization. These processes lead to increased wastewater production, making accurate quantification of GHG emissions from WWTPs critical for developing effective mitigation strategies and meeting international climate commitments. In Mexico, the National Institute of Ecology and Climate Change (INECC) has reported GHG emissions from the waste sector, including WWTPs, since 1997. However, these reports have been plagued by irregular updates and inconsistent methodologies, relying predominantly on Tier 1 estimations with default emission factors provided by the Intergovernmental Panel on Climate Change (IPCC). While these estimations offer a preliminary assessment, they often lack the accuracy required for informed decision-making and effective mitigation.

This study addresses this gap by evaluating the accuracy of Tier 1 estimations and emphasizing the need for direct measurements to improve Mexico's GHG inventories. The research compares data calculated by INECC with Tier 1-type estimations derived from operational data from over 250 WWTPs (treating >100 L s-1) based on the 2006 IPCC guidelines and their 2019 refinement. Additionally, a case study was conducted on two large-scale WWTPs in Mexico City with contrasting treatment technologies. One plant utilizes conventional activated sludge (CAS), while the other employs a more advanced anaerobic-anoxic-oxic (A2O) system combined with a membrane bioreactor (MBR) for nutrient removal (A2O+MBR). This selection facilitates a comparative analysis of GHG emissions across different treatment processes, providing a deeper understanding of the factors influencing emissions.

A simplified open flux chamber method was employed for direct CH? emission measurements. This method, designed with low technical complexity and minimal instrumentation, enabled quantification of emissions at the process-unit level within each WWTP. This approach provides a detailed analysis of emission sources and their relationship to plant operations.

The results reveal that GHG emissions are significantly underestimated when relying on IPCC Tier 1 estimations compared to direct measurements. This discrepancy is especially pronounced in the CAS plant, where direct measurements revealed emissions up to three times higher than Tier 1 estimates. Additionally, the study highlights the critical role of methane correction factors (MCFs). Incorporating locally determined MCFs resulted in a twofold increase in estimated emissions, even when these MCFs were determined indirectly. This underscores the necessity of using region-specific data for accurate emission estimations. Comparative analysis between the two WWTPs showed that the A2O+MBR plant, representing a newer and more advanced technology, emitted significantly more GHGs than the CAS plant. This difference is attributed to the anaerobic and anoxic units in the A2O+MBR process, which foster methanogenic conditions. These findings have significant implications for

selecting wastewater treatment technologies, particularly in developing countries, where decisions often require balancing treatment efficiency with environmental impact.

In conclusion, this study highlights the critical importance of updating emission inventories regularly and transitioning toward direct measurements to improve the accuracy of GHG estimations. Adopting direct measurement techniques can facilitate the shift to Tier 2 or 3 methodologies, resulting in more precise and reliable data. Such data is essential not only for research and modeling but also for designing effective mitigation strategies to reduce GHG emissions in the wastewater treatment sector. By providing a detailed analysis of GHG emissions from two contrasting WWTPs in Mexico, this study offers valuable insights and data to inform mitigation strategies in Mexico and other developing nations.

Assessing the Climate Resilience of Urban WASH Systems through Remote Sensing, GIS, and Land Surface Temperature Analysis + Mapping Climate Vulnerabilities of Urban WASH Systems with GIS and Remote Sensing

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Urban Water, Sanitation, and Hygiene (WASH) systems are integral to public health and sustainable urban development. However, they face increasing vulnerabilities due to climate-induced stressors, particularly in low- and middle-income countries (LMICs). Climate extremes, such as flooding, droughts, and urban heatwaves, disrupt WASH services and exacerbate inequities in access to clean water and sanitation, especially in informal settlements. These challenges call for innovative methodologies to assess vulnerabilities, including the integration of geospatial technologies. This study employs advanced Remote Sensing (RS) and Geographic Information Systems (GIS) techniques, with a specific focus on Land Surface Temperature (LST) analysis, to evaluate the spatial dynamics of urban WASH resilience under climate stress.

The research aims to address three critical questions:

1.How can RS and GIS techniques, including LST analysis, be utilized to map and monitor climate-induced vulnerabilities in urban WASH systems?

2.What spatial patterns emerge from the relationship between WASH infrastructure and climate risks such as flooding, heat stress, and water scarcity?

3.How can the findings guide evidence-based interventions to enhance the resilience of urban WASH systems?

The methodology integrates a multi-faceted geospatial approach, leveraging satellite imagery from Sentinel-2, Landsat, and MODIS, alongside ancillary datasets, including precipitation, elevation, and socio-economic data. A combination of spatial analyses and modeling techniques is employed:1.Flood Vulnerability Mapping: Precipitation, elevation, and land-use data are used to model flood-prone areas where WASH services are likely to be disrupted. Hydrological models are calibrated to simulate runoff patterns and identify infrastructure at risk, 2.Land Surface Temperature (LST) Analysis: LST data, derived from MODIS and Landsat, are analyzed to assess urban heat islands (UHIs) and their impacts on water quality, hygiene practices, and the efficacy of sanitation systems during heatwaves. Hotspot analysis is applied to map spatial clusters of extreme heat, with particular attention to densely populated areas lacking adequate green cover, 3.Temporal Land-Use Change Analysis: Historical satellite imagery is analyzed to monitor urban expansion and its implications for WASH infrastructure. The spatio-temporal dynamics of impervious surface growth are correlated with declining groundwater recharge and increased flood vulnerability, and 4.WASH Vulnerability Index (WVI): A composite index is developed using indicators such as proximity to water bodies, drainage density, population density, and LST anomalies. This index provides a quantitative measure of resilience across urban regions.

Preliminary results highlight the compounded effects of climate stressors on urban WASH systems, particularly in informal settlements. Flood-prone areas experience recurrent disruptions in sanitation services due to overwhelmed drainage systems, leading to water contamination and outbreaks of waterborne diseases. In contrast, regions with high LST values, typically associated with urban heat islands, face additional challenges. Elevated temperatures accelerate water evaporation rates, exacerbate water scarcity, and compromise the efficiency of wastewater treatment systems.

Spatial analyses reveal stark inequities in WASH service resilience. Informal settlements, characterized by limited infrastructure and high population density, are disproportionately affected. For example, flood modeling indicates that areas with inadequate drainage infrastructure experience prolonged waterlogging, contaminating potable water sources and rendering sanitation facilities unusable. Similarly, LST analysis reveals that informal urban cores are hotspots for extreme heat, where inadequate shade and ventilation intensify public health risks. The study also identifies temporal trends in urban land-use change that exacerbate vulnerabilities. Urban expansion into environmentally sensitive areas, such as floodplains and wetlands, increases exposure to flooding while reducing the natural capacity of ecosystems to mitigate these risks. Concurrently, the growth of impervious surfaces amplifies runoff and exacerbates urban heat islands, further straining WASH infrastructure.

Implications for Policy and Planning - The research provides actionable insights to inform climate-resilient urban planning and WASH interventions: 1.Spatial Vulnerability Maps: High-resolution maps delineate regions at greatest risk of climate-induced WASH disruptions. These maps enable stakeholders to prioritize resource allocation and infrastructure upgrades, 2.Integration of LST Data: By incorporating LST into vulnerability assessments, this study highlights the importance of addressing heat stress as a critical dimension of WASH resilience. Strategies such as increasing urban green cover and implementing heat-resistant sanitation systems are recommended, 3.Resilience Metrics: Quantitative indicators are developed to monitor and evaluate the performance of WASH systems under varying climate conditions, facilitating adaptive management, and 4.Policy Recommendations: Evidence-based strategies include enhancing stormwater management, decentralizing water storage, promoting climate-resilient building codes, and incorporating LST mitigation measures into urban planning.

This study contributes to global sustainability goals by aligning with Sustainable Development Goal (SDG) 6 (Clean Water and Sanitation) and SDG 11 (Sustainable Cities and Communities). The integration of LST analysis adds a novel dimension to urban resilience studies, addressing the often-overlooked impacts of heat stress on WASH services. By emphasizing equitable access to resilient infrastructure, the research advances social justice and public health objectives, particularly for marginalized communities in LMICs. This research demonstrates the transformative potential of geospatial technologies in assessing and enhancing the resilience of urban WASH systems to climate change. The integration of LST analysis with flood modeling and land-use change assessments provides a comprehensive framework for identifying vulnerabilities and guiding targeted interventions. By bridging the gap between scientific research and practical applications, this study empowers urban planners, policymakers, and stakeholders to build more sustainable, equitable, and climate-resilient cities.

Theme 2.1: Governance and Financing for Climate-resilient WASH

Financial Strategy for Inclusive Onsite Sanitation in Low-Income Communities in Urban Centers of Bangladesh

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Low-income communities (LICs) in urban centers of Bangladesh primarily rely on onsite sanitation systems, often using single pits or toilets connected to ponds or drains. Climate change-induced impacts, such as waterlogging and flooding from heavy rainfall, exacerbate the overflow of these pits, spreading untreated human waste into the environment. This situation underscores the urgent need for resilient toilet containment improvement. However, municipal authorities in Bangladesh lack robust financial strategies to sustainably deliver inclusive sanitation services. This study develops a comprehensive financial strategy to address these economic and infrastructural challenges, aiming to ensure resilient sanitation facilities for LICs in urban Bangladesh. The proposed strategy emphasizes engaging microfinance institutions (MFIs) to provide concessional loans to low-income households and sanitation enterprises to support business growth. It also advocates for dedicated sanitation budgets, investment plans, and transparent monitoring mechanisms. Recognizing the inadequacy of government funding, the strategy suggests leveraging resources from private sources, local enterprises, MFIs, and households to bridge financial gaps. The primary objective of this study is to establish a sustainable financing mechanism for sanitation services by integrating MFIs into the sanitation service chain. The methodology involved a needs assessment to identify challenges, a review of existing policies, and qualitative analyses conducted in two geographical locations in Bangladesh. Recommendations were drawn from consultations with LIC residents, municipal authorities (Pourashavas), MFIs, Local Sanitation Enterprises (LSEs), and sector experts, alongside feedback from validation workshops. The strategy was piloted in two cities, followed by assessments to evaluate its feasibility and acceptance. This study focuses on enhancing institutional arrangements to engage MFIs and LSEs in providing access to affordable loans and appropriate sanitation technologies. The strategy serves local government institutions (LGIs), non-government organizations, MFIs, LSEs, and other stakeholders working to improve sanitation in LICs. While Pourashavas occasionally fund extreme-poor households through various projects, they lack strategies to financially support LSEs or facilitate access to soft loans for low-income households. Limited availability of climate-resilient solutions tailored to local contexts further impedes improvements. LIC households, constrained by financial limitations and high-interest loan rates, struggle to invest in toilet upgrades. Moreover, awareness about climate-resilient sanitation technologies and available services remains low. To address these issues, a tripartite agreement among Pourashavas, LSEs, and MFIs was established, delineating clear roles for each party. Pourashavas allocated dedicated budgets, monitored implementation, and enforced regulations, while MFIs provided soft loans through existing community groups. Simultaneously, LSEs were empowered to produce high-quality sanitation solutions, with demand generation facilitated through community engagement.

Municipal authorities play a pivotal role in managing contracts with LSEs and MFIs, capacity building, demand generation, and regulatory enforcement. The strategy aims to strengthen institutional systems to support toilet containment improvements through a sustainable financing mechanism. Key components for success include: 1.

Soft loans for low-income households and LSEs, 2. Subsidies for extreme-poor households through government funds, and 3. Regulatory enforcement for non-poor households. To achieve these objectives, the strategy focuses on - 1. Community awareness campaigns to motivate households, and 2. Capacity-building training for LSEs and masons to ensure quality standards.

Climate-resilient toilet containment structures are essential for achieving safely managed sanitation. Establishing a sustainable financing mechanism is critical to maintaining these facilities and adapting to climate change impacts. Municipal authorities, as mandated service providers, must lead efforts to engage private sanitation enterprises and MFIs in inclusive service delivery. While this strategy proposes an innovative financing model, its implementation requires strong collaboration among stakeholders and sustained commitment from Pourashavas, MFIs, and LSEs. Financial contributions from both the Government of Bangladesh and private sectors are vital to ensure scalability and long-term success.

Governance for Inclusive and Climate-Resilient WASH: A Study of Uttar Pradesh

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Climate change, urban risks, and vulnerabilities significantly impact the delivery of municipal services and the quality of life in urban areas. Uttar Pradesh, situated centrally in northern India, faces unique challenges in balancing urban development with sustainability. In response, the state government has initiated a range of state-sponsored development schemes aimed at establishing green and sustainable infrastructure, inclusive civic amenities, and institutional reforms for the effective delivery of municipal services. These initiatives complement centrally sponsored urban missions, including the Smart Cities Mission, AMRUT 2.0, Swachh Bharat Mission 2.0 (SBM 2.0), Pradhan Mantri Awas Yojana (PMAY), DAY-NULM, and the Prime Minister SVANidhi Scheme. Additionally, state-level initiatives such as the Mukhya Mantri Nav Srijit Nagar Yojana and Mukhya Mantri Vaiswik Nagrodaya Yojana aim to enhance civic amenities by improving urban infrastructure, sanitation, water supply, waste management, and overall quality of life. AMRUT 2.0 emphasizes promoting a circular economy of water by expanding water connections, ensuring the sustainability of water resources, and prioritizing the recycling and reuse of treated sewage. It also focuses on rejuvenating water bodies and enhancing water conservation. Similarly, SBM 2.0 prioritizes garbage-free cities and effective wastewater management. Meanwhile, the Smart Cities Mission aims to improve urban resilience to climate change and disasters.

Water, Sanitation, and Hygiene (WASH) are integral to achieving Sustainable Development Goals (SDGs), particularly SDG 6 (clean water and sanitation), SDG 3 (good health and well-being), and SDG 11 (sustainable cities and communities). Despite this, the WASH infrastructure in India, especially in urban areas, remains inadequate. Uttar Pradesh, the most populous state in India, grapples with significant issues in urban water management, sanitation, and public hygiene. Addressing these challenges is critical for achieving the SDGs, as WASH services directly impact health, education, and gender equality. Ensuring sustainable WASH infrastructure is not only essential for Goal 6 but also has a cascading effect on other SDGs. Freshwater, an essential resource for human life, is under severe threat due to rapid urbanization, unsustainable usage, and global warming. The mismanagement of water resources, including over-extraction, pollution, and encroachment, has exacerbated these challenges. Since 2012, water-related issues have consistently ranked among the top five global risks. To safeguard water security for future generations, integrated water resource management is imperative. India has made significant strides in addressing water concerns through national missions and programs that promote river-sensitive urban development. However, a transformative approach is needed to revamp urban water management and infrastructure. Planning and implementation in the urban water sector must adopt a transdisciplinary approach grounded in systems thinking.

Small and micro entrepreneurs in peri-urban and rural water service delivery: Prospects & Challenges in Bangladesh and beyond

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Water and sanitation service provision is no more a domain of the governments only. There are many actors that have come on board to provide the water and sanitation services to those communities that are underserved and / unserved as gap fillers, majority providing these crucial services in rural and peri urban areas (Kubasu & Mbuvi 2018). In Bangladesh, while 98% of the population has basic water access, only 59.1% have safely managed services (JMP 2022). Challenges like poor water quality, unsustainable infrastructure, and climate change, especially in coastal areas, persist. To address these, Bangladesh has opened the WASH sector to businesses, with NGOs and development partners working to improve conditions. The rural water service delivery of other South Asian countries is no different. This paper reviews the challenges faced by organisations engaged in promoting WASH businesses and highlights the potential for the private sector with the right enabling conditions. This research used a mixed-methods approach (Gain et al., 2022), including a world café workshop with stakeholders, two roundtable discussions with WASH partners, a literature review, and the authors' professional experiences. During the roundtables, partners shared field experiences, challenges, and organizational data. Based on these discussions, this paper reviews the findings, field observations, and expert insights.

The review concludes that private partnership models as well as the private service models can be grouped into three broad categories. While the City Corporation and municipalities level WASH Services can be considered as large entrepreneurs, the Sub-district level WASH service, private water kiosks operators, community level mini pipe water schemes can be considered as small or micro entrepreneurs. The review thereafter more focuses on small and micro entrepreneurs highlighting the challenges of their community level services.

Based on the outputs of the workshops and round tables discussions, the challenges that slow down the progress or hinder the achievement of results can be summarized as: 1. Private entrepreneurs do not scan the market methodically before starting the business. Most of the private water entrepreneurs have dived into this business for quick return, 2. Private (small and micro) water entrepreneurs are not considered for green financing (concessional loans). In fact, commercial banks do not yet consider it as a proper sector for financing. So entrepreneurs rely on microfinance on informal sources for investment, 3. Microentrepreneurs do not have the skill or institutional support to make their project bankable. There is no specialized training (vocational or business) available for private water entrepreneurs that can help them institutionalize the business and 4. The Local Government Institutes (LGI) are authorized to regulate these private sector players. But often they do not have the capacity to regulate these private players.

Engaging the private sector in WASH is seen as key to improving sustainability, but challenges like access to finance, supply chain capacity, and the enabling environment remain. Some of these challenges are unique and some are common for micro entrepreneurs in South Asia. Lack of finance and insufficient regulatory support are

two areas where the sector can get knowledge from its neighboring countries. A coordinated approach involving banks, local government institutions (LGIs), and private sector actors is crucial. Despite challenges, the small and micro entrepreneurs in Bangladesh have created a market ecosystem in climate vulnerable areas and delivering services which can be an inspiration for other.

Engagement of Urban SHGs in WASH, Strengthening Urban Livelihood and Adaptive Social Protection

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Around 25 percent of India's population (about 81 million people) live in urban areas on incomes that are below the poverty line (UNDP, India: Urban Poverty Report 2009). The vulnerability of urban poor population is not simply a function of risk and/or shocks, but also because of preexisting socio-institutional context . Adaptive Social Protection (ASP) measures designed recognising the complexity of urban poverty, which is a result of low income or lack of skills, exposure to multiple risks, economic downturns, natural disasters, and the growing adverse impact of climate change, go a long way in addressing urban poverty and vulnerability. Therefore, strengthening livelihoods of urban poor and particularly women and those engaged in vulnerable population, and ASP interventions not only make them more resilient to shocks and/or disaster related vulnerability, but also help addressing more insidious root causes of vulnerability and breaking the cycle of poverty.

India's 74th Constitutional Amendment Act, 1992, and National Urban Livelihood Mission (DAY NULM), 2013 mandate the Urban Local Bodies (ULBs) to address vulnerabilities of urban poor through grassroot institution building, skilling and engaging SHGs in sustainable livelihoods as well as WASH. Based on the DAY-NULM and Swachh Barat Mission (SBM) Convergence Guidelines (2018) issued by Ministry of Housing and Urban Affairs (MoHUA), Government of India, several states have issued directives to the cities to identify, enumerate, collectivise the urban poor women and engage their SHGs in WASH. The urban poor women and people in vulnerable occupations such as informal sanitation work, waste picking and the trans-people, who are at risk of livelihoods, are collectivised into self-help groups (SHGs) and are engaged in operation and maintenance of urban WASH facilities and building the last mile connectivity in service delivery. These urban vulnerable communities now have secured livelihoods, and they are better equipped to cope with and overcome the moments of stress and/or crisis without exploiting the supply of natural resources. The SHGs are not just managing the operation, maintenance and service delivery, but now play a critical role in deciding WASH requirements of the community.

Urban Management Centre (UMC) conducted a landscape study to understand the engagement of women led SHGs in WASH sector across 10 cities of India through convergence of SBM and DAY-NULM. This paper presents the learning from this study and UMC supported interventions in Odisha and suggests recommendations towards strengthening urban livelihoods and Adaptive Social Protection (ASP) of urban poor women SHGs, especially in WASH sector. The methodology adopted in the landscape study covered sample survey, key stakeholders' questionnaire and focused group discussion across, three categories of SHGs - a. SHGs traditionally involved and engaged in WASH activities, b. SHGs that are formed of vulnerable groups of Rag pickers and street sweepers, and c. SHGs that were not engaged in any livelihood and gauge their willingness to adapt WASH based livelihood.

The study also revealed the crucial enablers and mechanisms that encourages and supports the livelihoods of SHGs across the value chain of WASH such as - a) Absence of state policies and directives discourages ULBs

initiative, minimizing engagement of SHG in WASH livelihoods, b) The performance of engaged SHGs is far more effective, when ULBs provide them with "enabling mechanisms" such as a clear mandate, contractual agreements, training and skilling, c) All the larger cities/ corporations have outsourced WASH services and its O&M, to private contractors. The absence of enabling mechanisms, SHGs' engagement as contractors' human resources is absent, depriving the informal workers and waste pickers from being part of WASH linked livelihood opportunities, despite their expertise, skills and willingness to work, and d) SHGs engagement in Sanitation based components is minimal, owing to absence of technical skillset and technical challenges under ULBs.

The paper also highlights the key learnings from the interventions in Odisha with technical support from UMC such as - a) With a sustainable livelihood, the urban poor women, sanitation workers, waste pickers and transgender SHGs are better prepared for, cope with and adapt to shocks such as natural disasters, economic downturns, and public health crises, b) The ASP interventions are tailored, inclusive and responsive to the specific needs of these people and supported by institutional frameworks, c) The ASP interventions involve four categories of social protection: protective (coping strategies), preventive (coping strategies), promotive (building adaptive capacity), and transformative (building adaptive capacity), d) Targeted interventions like need-based capacity building, process-related skilling, financial and digital literacy and communication skill training have resulted in increased access to economic opportunities and sustainable livelihoods and impacted in terms of improved voice and agency of the urban poor, e) Establishing standard terms of contract, timely and transparent digital payment of wages, personal protective equipment and periodic health check-up, risk and hardship allowance, monthly paid leaves, uniforms and protective shoes, life and accidental insurance, lounge and individual locker facility, separate toilets for male and female and Prevention of Sexual Harassment at workplace go a long way in ensuring safety and dignity of WASH workers in Odisha, and f) The cities in Odisha have been provided with funding support to meet the gap from the revenue collected from the citizens for the WASH services, which is provisioned from the central and state sources.

Sustainable Water Governance and Climate Resilience Through Community Leadership: Insights from Odisha's Jalasathi Model

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The Government of Odisha has prioritized achieving universal piped water supply for urban households with an emphasis on quality, sustainability, and resilience. Recognizing the intersection between water management and climate change, the Jalasathi initiative was launched in 2019 by the Housing and Urban Development Department of Govt. of Odisha. This integrates community-led governance to ensure equitable and sustainable water supply systems. Women Self-Help Groups (SHGs) under the National Urban Livelihoods Mission are engaged as community partners, fostering participatory governance and promoting resilience against climate impacts. As of March 2024, approximately 809 active Jalasathis operate across 115 Urban Local Bodies (ULBs) in Odisha. These women SHG members facilitate user charge collection, enable new water connections, regularize unauthorized connections, and identify service delivery issues and maintenance needs. Additionally, Jalasathis raises awareness about the importance of reducing dependency on groundwater and promoting the use of piped water systems as a sustainable and climate-resilient alternative. The Jalasathi program is designed with objectives that align with sustainable water management and climate resilience. It seeks to achieve universal metered piped water connections across urban local bodies (ULBs), thereby reducing reliance on groundwater and mitigating over-extraction. The program ensures transparency and efficiency through doorstep billing and digital payment systems, while enhancing water quality monitoring by conducting regular consumer-level tests. By promoting consumer awareness about sustainable water use and integrating climate resilience practices, the program addresses critical environmental challenges. Furthermore, the timely resolution of grievances enhances service delivery and consumer satisfaction. These efforts collectively contribute to climate change mitigation and adaptation by reducing dependence on unsustainable water sources and leveraging digital tools for efficient water governance.

Governance and Stakeholder Mapping - The program's multi-tiered governance involves the Housing and Urban Development Department (H&UDD), WATCO, PHEO, and SUDA, ensuring seamless implementation and monitoring. The functional roles of stakeholders were analyzed to develop a governance framework that incorporates climate resilience practices. Jalasathis bridges the gap between consumers and service providers, fostering trust and accountability. Capacity-building efforts empowered Jalasathis to integrate climate-resilient approaches in water management.

Capacity Building for Climate Resilience - Training modules designed for Jalasathis emphasize participatory learning, climate awareness, and operational efficiency. The curriculum includes: 1.Roles and responsibilities of Jalasathis in climate-resilient water governance, 2. Using digital tools like mPoS machines for efficient service delivery, 3. Conducting water quality tests to address contamination risks exacerbated by climate variability, 4. Communication strategies for consumer interaction and education on climate-smart water usage, and 5.

Complaint redressal mechanisms to enhance service delivery. Interactive sessions focus on sharing best practices, addressing operational challenges, and fostering collaboration between officials and Jalasathis. Special sessions on gender inclusivity and climate adaptation were included to ensure equitable participation and address the disproportionate impact of climate change on women.

Knowledge Management and Digital Tools - The development of a state-level knowledge portal and Android application underscores the integration of technology in capacity building. The portal provides resources on water management, climate resilience, and best practices in Odia and English. It also features assessment tools and self-paced learning modules, enabling Jalasathis to adapt to evolving challenges. By promoting data-driven decision-making, the portal enhances the program's capacity to respond to climate variability.

Climate Change and the Jalasathi Model - The Jalasathi initiative aligns with climate adaptation goals by promoting efficient water use, reducing dependency on depleting groundwater reserves, and improving urban water system resilience. Periodic water quality testing mitigates health risks associated with climate-induced contamination. The focus on digital tools and consumer awareness campaigns fosters a culture of sustainable water use, critical for building climate-resilient urban communities.

The Jalasathi initiative exemplifies the integration of community-led governance, gender empowerment, and climate resilience in urban water management. By leveraging the strengths of women SHGs and digital innovations, the program addresses both immediate service delivery challenges and long-term climate adaptation needs. Continued investments in capacity building, digital infrastructure, and stakeholder collaboration will further enhance the program's impact, positioning Odisha as a leader in sustainable and climate-resilient urban water systems. The success of the Jalasathi model in Odisha has inspired its replication at the national level through the AMRUT Mission's "AMRUT Mitras" initiative. AMRUT Mitras leverages the community-driven approach and women-led governance principles of the Jalasathi model to enhance urban water service delivery across diverse contexts. Tailored interventions and localized capacity-building efforts ensure that the model addresses the specific needs of urban areas while promoting sustainable and equitable water management practices. This abstract reflects the transformative potential of the Jalasathi initiative in achieving sustainable WASH outcomes in the context of climate change.

Theme 2.2: Governance for Climate-resilient WASH

Climate Change Induced Water Disasters in Nepal

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Climate change has already started water crisis in different parts of the world likely intense floods, long droughts and many more. The most severe impacts of climate crisis will already have realized and its water disasters. If coping action will not start soon, impacts will be worst in coming days. As per the Intercontinental panel for climate change (IPCC) forecast currently two billion people across the world are living with water-stressed situation. The Intergovernmental Panel on Climate Change expects disasters – which are mostly water-related – to rise across the world. The world's poorest, who have contributed very little to greenhouse gas emissions, are hardest hit. There is a real risk that low-income countries are pushed into a vicious cycle of worsening poverty.

Climate change impact has been observing since some years. The glacier lake outburst is the cause of failure of dam the containing a glacier; where a water body contained by a glacier melts of overflows the glacier. Those dams contain a glacier ice, failure can happen due to erosion and buildup water pressure an avalanche of rock or heavy fall of snow. Increasing glacier lake outburst is due to climate change effect, alongside environmental effects of climate change. This is especially true in the Himalayas where geologies are more active. The outburst floods from glacier-dammed lakes typically entrain, transport, and deposit large amounts of sediment. If the channel is steeper and contains abundant loose sediment, the flood carries and transform as a debris flow. There are several glacier lakes lies upstream of northern Himalayan region. As of climate change effects those upstream lakes are in threat that has warned floods and landslides, projected increasing the days to come. Those glacier outburst is triggered by the temperature rise combined with continuous rainfall during monsoon. The natural calamities, such as landslides and floods, along with the continuous melting of mountains and glaciers, pose regular threats to the downstream communities and loss of natural resources and biodiversity. These are consequence result of environmental hazards that we are not responsible.

Nepal continues such disasters; in June 2021: Bhremathang of Helambu region, Sindhupalchok outburst a glacier lake has effects downstream community, huge losses of human and property. Similarly, in August 2023, Kagbeni village of Mustang district suffered the same. Such extreme events surprised as it was due to unusual and beyond the community people's imagination. Recently, there was glacier lake outburst in Thame village of Solukhumbu district. It has been confirmed that the flood in Thame was caused by the outburst of two glacier lakes among the five located in the high Himalayan terrain. It has been learnt that most of the glacier lake in high Himalayan forms in result of glacier retreats and meltwater fills whole left behind. The main cause of outburst of glacier lake during monsoon. Firstly, as of rising of temperatures snow melts in dam that makes full of water in dam, secondly heavy rainfall results fast melting of snow results the dam full of water. Similarly, the rapid slope movement into the lake, flood from a lake from upstream.

The local community needs to become more aware of Glacier Lake Outburst Flood (GLOF) hazards and ways and means to respond to warnings. It is important to continue dissemination of accurate information to the public by the mobilizing media. Additionally, it is imperative that a national policy be developed for increasing awareness, early warning, and risk mitigation. This could then be used as a template for application to the entire Hindu Kush-Himalayan region. Furthermore, immediate action is urged along the following lines: increase of public awareness; more extensive vulnerability assessment; routine airborne and satellite monitoring; and more intensive and repeat geophysical survey. Resilient landscapes, with the water cycle in balance, is essential to avoid dangerous tipping points and dramatically rising temperatures. By protecting ecosystems and using nature-based solutions in the planning of human societies, we all become safer. Protected forests and wetlands can for example store carbon, recharge groundwater and provide a buffer against storms.

Ecological Planning and Design for Peripheral Urban Waterbodies: A Case of Ahmedabad City

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Rapid growth of Indian cities adversely affects many urban and peri-urban waterbodies which play a significant role in local and macro ecosystems as well as resident community's livelihoods. Although growth of cities is inevitable, loss of urban waterbodies will significantly decrease resiliency of urban areas as they lose capacity for climate change impact, carbon footprint increase, and temperature increase.Growth of many Indian cities is guided by framework of Development Plan and realised, specially in Gujarat, through vehicle of Town Planning Schemes. However, TP schemes do not consider ecological drivers such as catchment areas and drainage patterns which are crucial to the existence of waterbodies. This disjunction results in loss of lakes' micro and macro ecosystem networks and hence their significant role in local ecosystem, livelihoods, and as natural drainage system. As physical boundaries of plots are demarcated, many ecological and livelihood patterns get disrupted such as lakes' catchment, natural water drainage, movement of wild and domestic animals and hence animal husbandry, and access to water for farming. While our urbanisation has disregarded our natural environment and hence weakened the city's tolerance for climate change impact, further growth on the periphery adds concerns over equity in access to natural waterbodies changing existing livelihoods.

This paper suggests ecological study of larger areas are required before laying a TP scheme and in meso scales, an ecological design of these waterbodies as public spaces using nature based strategies can help maintain these waterbodies. Peripheral lakes and streams are dependent on their larger water network and water processes. Hence documentation of natural drainage pattern and catchment areas should form the basis for planning and design decisions made for and around these water bodies. At micro scale, ecological design of these lakes help mitigate climate change impacts by acting like a sponge for the area and preventing urban floods, decrease temperatures due to park-cool-island-effect and natural wetlands, and other ecological services. Sources of water are another area to be addressed, specifically as catchment areas of these waterbodies will significantly shrink after implementation of TP. As the ground will get reshaped through development of individual plots, the drainage pattern will get disrupted. This issue can be addressed partially through design of topography within plot boundary of lakes or streams and partially through considering other water sources, such as run-off from adjacent areas and treating storm water and directing it towards water body. Treated STP water that gets directed needs to be tested in terms of its quality before being sent to waterbodies.

The paper will suggest a layer-wise documentation of ecosystem and dependency of its elements of water, ground, and vegetation in two scales: Micro-ecosystems and Macro-ecosystem. There is a need for an in-between scale framework (between DP and TP) so these ecological networks can be understood in a comprehensive and interconnected manner. Within the revenue boundary of lakes or streams in TP, strong impacts can be achieved through Nature based solutions and a layered masterplan, these together can increase chances of survival for waterbodies and can benefit the citizens directly and indirectly.

The findings to be presented in paper are arrived at through study of selected peripheral lakes and stream in Ahmedabad city. The developed framework for studying and strategies for ecological design of these peripheral water bodies will be presented. These strategies achieve ecological harmony while introducing new human activities to align with assigned public use of the lake by town planning scheme. By respecting existing ecological networks such as flora and land covers, fauna habitats like wetlands and nesting sites continuity in meso-ecosystems can be achieved. The waterbody's role in natural water drainage patterns as well as flood mitigation can be maintained through landform considerations. This can prevent urban flooding due to changed precipitation patterns and in the longer run increase aquifer levels through better water infiltration.The number and large spread of urban peripheral lakes make them accessible for a larger population of residents and create potential for addressing ecosystems at the meso-scale. We recognise the need for guidelines for achieving TP schemes that support larger scale ecological networks.

Water-Energy-Food Nexus Governance in India addressing farmers' inclusivity and climate impacts

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The governance structure in India is a three-tiered system that is local, state, and central. The water, energy, and food sectors play a very important role in the development of the country. The sectors are hugely interdependent and interrelated, and yet the departments of all these sectors work in silos. It is not only restricting the country from holistic and comprehensive development but also putting a restraint on sustainable development. In this research, the governance of all three sectors has been studied in depth at all three levels. This includes an analysis of the literature on WEF at the global and national levels. At the national level, the investigation of the five-year plans, budget outlay, and administrative structure has been done and presented for all three sectors highlighting the gaps and scope. At the local level, the case study of the Bundelkhand region and Banda District has been presented with parameters for socioeconomic profile and institutional set-up. A primary survey of eight blocks and one Municipal Council was conducted in the Banda District to identify the issues pertaining to WEF security and who is responsible for it (as per stakeholders). In Banda District, 85% of the population resides in rural areas, and findings revealed that the major reason for crop failure is animal attack, water scarcity, lack of infrastructure, and climate change. The result shows that 73% of the population thinks that both central and state government is responsible for farmers' poor condition, and the reasons are lack of a grievances addressal system, faulty policy, and negligence. Based on the analysis, policy recommendations have been made that would help strengthen the governance structure and will address the issues of the population and bring transparency. The departments of all three sectors must work in an integrated manner to achieve sustainability which will lead to socio-political development.

A study on Climate-Resilient WASH in disasters: Addressing Gaps in Disaster Waste Management in Kerala, India

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Kerala is highly vulnerable to natural disasters due to its coastal location, steep Western Ghats terrain, and dense population (860 people/sq. km). The Kerala State Disaster Management Plan identifies 39 hazards, both natural and anthropogenic. Disaster waste refers to waste generated during and after disasters, including debris from destroyed infrastructure, damaged relief goods, and packaging from response operations. Inefficient disaster waste management can cause disease outbreaks, water contamination, and environmental degradation, worsening disaster impacts. Effective disaster waste management is crucial for ensuring safety, facilitating emergency response, reducing economic losses, and preventing further casualties by quickly clearing debris. The study explores how Kerala's Water, Sanitation, and Hygiene (WASH) systems respond to climate-induced disasters, identifying gaps and challenges. It aims to develop a climate-resilient protocol for managing disaster waste, ensuring both immediate recovery and long-term preparedness in disaster-prone regions. This study aims to develop a scalable and climate-resilient protocol for disaster waste management in Kerala to bridge critical gaps in WASH service delivery during climate-induced disasters. The specific objectives are: Assess how existing WASH systems perform under the pressures of climate-induced disasters, Identify governance related gaps and challenges for WASH services during climate-induced disasters and Develop a protocol for climate-resilient WASH systems that can adopt in a disaster waste management.

This study is in-depth qualitative research intended to assess how existing WASH systems perform under pressure climate-induced disasters and identify the systemic gaps and challenges for WASH services during such incidents. The data was collected using interview guides from the multi-stakeholders including panchayat officials, district Suchitwa Mission officials, state Suchitwa Mission officials, officials of empanelled agencies and Haritha Karma Sena members. The insights gained will contribute to the development of a protocol for climate-resilient WASH systems to be adopted during future disasters. With natural disasters increasing in frequency and severity, effective disaster waste management is critical to reducing environmental and public health risks. The absence of standardized protocols makes sorting and managing large-scale waste challenging, especially in developing countries where solid waste systems are underfunded and disorganized. Current waste management practices lack integrated approaches to resource utilization and recycling, with capacity gaps further exacerbating the issue. Existing Solid Waste Management guidelines in India are insufficient for handling post-disaster waste surges, complicating response efforts and posing safety risks. This study addresses the urgent need for a climate-resilient disaster waste management protocol by identifying governance gaps, evaluating WASH services under pressure, and providing actionable strategies to improve disaster preparedness and long-term resilience.

Enabling Environment - Disaster waste management is not prioritized during emergencies, with a lack of clarity on managing debris, construction and demolition (C&D) waste, and defining institutional roles for activities such as assessment, procurement, and monitoring. Resources - Insufficient funds for disaster waste management forced

panchayats like Kainakary and Vanimel of Kerala to rely on limited local resources, with reimbursement plans for post-disaster expenses. Infrastructure and Technology - A lack of sufficient storage facilities, such as Material Collection Facilities (MCFs) and Resource Recovery Facilities (RRFs), worsens waste management during disasters. In Alappuzha, rapidly filling septic tanks in relief camps, due to elevated water tables and increased toilet use, created sanitation challenges. Digging compost or soak pits during floods becomes impossible, and the district faces insufficient Faecal Sludge Treatment Plants (FSTPs). Limited technology upgrades and awareness hinder preparedness, and non-biodegradable waste management lacks centralized treatment facilities. Extreme floods disrupt Haritha Karma Sena waste management services. Managerial and Administrative - Flood alerts prompt panchayats to act, but waste removal depends on linked agencies, impacting timely responses. A lack of institutional monitoring mechanisms and standardized waste assessment systems further complicates disaster waste management. Panchayats face challenges in maintaining reliable databases on relief camp waste. Capacity Building - No disaster-specific training or capacity-building programs were provided to Suchitwa Mission teams or panchayats. Community Participation and SBCC - Social and Behaviour Change Communication (SBCC) materials for emergency waste management were unavailable and had to be developed during the disaster response. Inclusion - Relief camp toilets, including bio-toilets, were not inclusive, posing accessibility challenges for disabled individuals, pregnant women, and children.

These findings highlight critical gaps in funding, infrastructure, governance, and inclusion, emphasizing the urgent need for a robust, climate-resilient disaster waste management protocol. The study identifies critical challenges and offers practical recommendations to enhance WASH services in disaster waste management in Kerala. The key challenges include the lack of clear disaster waste management protocol, limited resources and infrastructure and inefficient capacity building and training, specific to disaster waste management among the stakeholders. These issues unaddressed, exacerbate the environmental and health risks associated with disaster waste. Strategic recommendations include strengthening existing waste management system, capacity building, promoting climate adaptive technology, enhancing interdepartmental coordination, promoting community-based waste management, and ensuring sufficient resources for disaster waste management activities. By institutionalising these practices and ensuring proper safety protocols, Kerala can improve its resilience to disasters, effectively manage disaster-generated waste, and promote sustainable environmental outcomes.

Exploring the climate-sanitation nexus in rapidly urbanising towns in Asia and Africa: a climate justice perspective

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The rapid pace of climate change is set to reverse many of the gains made in development and exacerbate existing challenges. This is a cause of concern for the sanitation sector where 1.5 billion people still lack access to basic services. Although there is now an increasing policy emphasis to link sanitation outcomes with climate change, we argue for the need to consider the impacts beyond sanitation access to include impacts present along the entire value chain. This, however, is particularly challenging in rapidly urbanising areas where the impacts and associated costs of climate-driven hazards may be further compounded by unplanned, informal development and poor provision of services that magnify vulnerabilities.

In this study, we analyse recent evidence from rapidly urbanising towns in Asia and Africa to shed light on some of these challenges, intersections, and blind spots in these off-grid areas. We ask: how is vulnerability compounded in the context of climate hazards and how do these (re) produce diverse forms of off-grid patterns? This paper draws on the multi-disciplinary research carried out under the BROWN GOLD project between 2020-2024 in Alleppey (India), Gulariya (Nepal) and Mekelle (Ethiopia) drawing on social science (document reviews, interviews, focus group discussions), natural science (sanitary survey, shit flow diagrams, water quality analysis), visual and creative methods (photovoice, photo-elicitation).

We show how climate uncertainty and high variability such as increases in the frequency and intensity of climate extremes (droughts, floods, and heatwaves) are magnifying structural inequities in these off-grid locations. Drawing on the lens of climate justice, we highlight the importance of the temporal and spatial context (when hazard strikes, where and for whom) in understanding both short and long-term impacts of the climate-sanitation nexus. By providing key entry points to reimagine WASH under increasing climatic uncertainty we hope to contribute to more just, inclusive, and sustainable outcomes for all, including marginalised communities.

Gender Equity and Social Inclusion at the center of system strengthening

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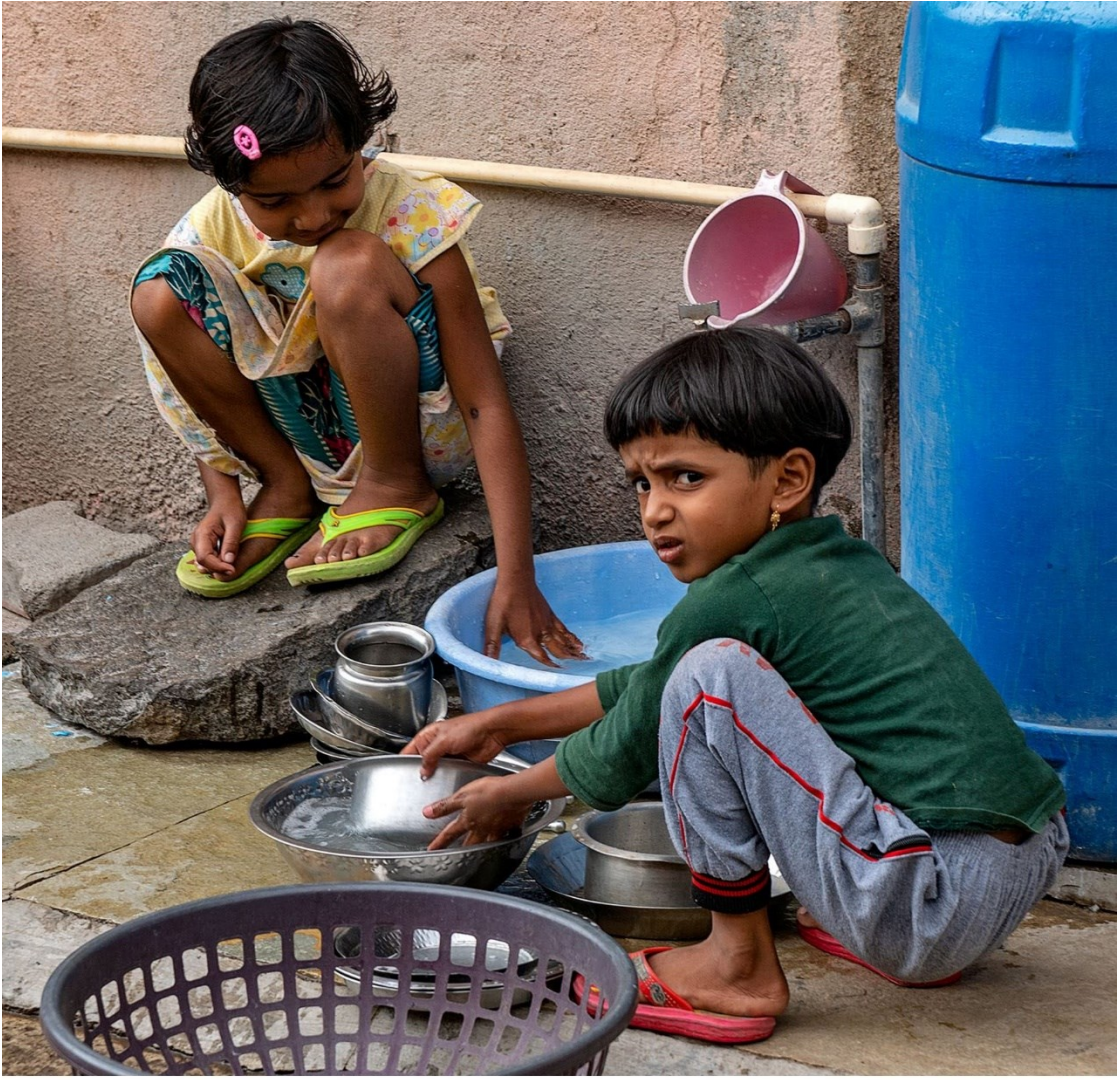
Water, sanitation and hygiene has traditionally been considered a techno-managerial sector. People are often not considered a part of planning, management and governance of water, sanitation and hygiene services. We have moved from a focus on infrastructure in MDGs to services in the SDGs. However in many places, the approach and challenges on the ground are still infrastructure focussed. In ensuring the infrastructure function and provide sustainable services to all, the need for systems strengthening has been reiterated. It is significant in this narrative to bring social and inclusion aspects as apart of the narrative from the start, not as an additionality or an afterthought or tokenism. Similarly, for the WASH services to be sustainable, there is a need to be climate resilient. As part of the WASH systems for Health supported by FCDO, the WASH Facility (IRC WASH, University of Leeds and London School of Hygiene and Tropical Medicine) is working towards bringing gender equity, social inclusion and climate resilience perspective in to the center of WASH systems strengthening. The project is being implemented in Bangladesh, Nepal, Sierra Leone, Malawi, Tanzania and Nigeria. The WASH Facility is developing a Learning Brief and an online course as part of the efforts. In our verbal presentation we should like to share this perspective and approach. We believe that the participants will learn about –

- Why these considerations?
- What needs to be considered?
- How can this be prioritised in different contexts?



Theme 3.1: Inclusive and Climate-resilient Water Systems

Drinking Water Governance, Management Efficiency, GESI Integration, and Sustainability Strategies: A Case Study of 63 WSUCs in Godawari Municipality

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The Constitution of Nepal, under Article 35, clearly mentioned access to clean drinking water as a fundamental right for all citizens. The responsibility for ensuring safe drinking water services is shared to three tiers of government. However, the governance of drinking water remains a critical challenge in Nepal, directly tied to the management capabilities of service providers.

Around eight different water management model are practicing in Nepal, among which the Water and Sanitation Users Committee (WSUCs), numbering approximately 43,000 nationwide, serve major population of Nepal.

This study focuses on 63 WSUCs within Godawari Municipality, located in the southern Kathmandu Valley. These WSUCs collectively manage 86 water supply schemes, service drinking water for 19,471 households—benefiting a total population of 97,633. The research investigates key aspects of WSUC governance, including tariff-setting processes, collection mechanisms, and the integration of Gender Equality and Social Inclusion (GESI) in executive committee of WSUCs. It also evaluates the management strengths and strategic approaches employed by the WSUCs to ensure the sustainability and functionality of water supply systems (WSS).

Data collection for the study was facilitated by the NWASH app, developed by the Ministry of Water Supply. A structured questionnaire survey key representatives of 63 WSUC members, complemented by a comprehensive review of legal documents and organizational records to ascertain the legal status and functionality of these committees. The analysis highlights 18 critical components essential for the effective management and operation of water supply systems, offering valuable insights into WSUC practices.

Exploring Water Scarcity from the Lens of Water Governance in the Ridge Town of the Himalayas: From Colonial Legacy to Contemporary Challenges and Future Prospects of Darjeeling

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As water scarcity intensifies globally, inclusive and effective governance becomes a critical determinant of sustainable water management, particularly in ecologically fragile and socially diverse regions such as the Himalayan ridge towns. This study examines the complexities of water governance in Darjeeling, India, where colonial legacies intersect with contemporary socio-economic and environmental challenges. Using the OECD Water Governance Framework, the analysis highlights systemic gaps, particularly in fostering equitable community engagement, cross-sectoral integration, and gender inclusivity.

The findings reveal a dichotomy between the commodification of water resources and the erosion of traditional community-based water management practices, further compounded by fragmented institutional mandates and limited representation of marginalized groups in decision-making processes. The paper emphasizes the importance of re-evaluating legal frameworks to promote inclusivity, equity, and resilience in water governance.

By integrating diverse voices—including local communities, women, indigenous groups, and civil society—into water management strategies, this study advocates for a paradigm shift towards more inclusive, adaptive, and participatory governance models. The research underscores that addressing Darjeeling's unique hydrological and socio-cultural dynamics requires innovative governance approaches that bridge the gap between policy and practice, ultimately contributing to sustainable water security in vulnerable mountain ecosystems.

Building Resilience: Integrating WASH and Vulnerable Communities into City Climate Action Plans, Case of Chennai

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Indian cities are increasingly vulnerable to the cascading impacts of climate change, experiencing intensified monsoonal flooding, prolonged droughts, urban heat and rising sea levels. These challenges are acutely visible in Chennai, which disrupts livelihoods and highlights the urgent need for climate-resilient urban planning. Vulnerable populations residing in informal settlements are disproportionately affected, lacking reliable access to water, sanitation and hygiene (WASH) services. Core Sanitation Workers (CSWs) are integral to the functioning of the liquid waste management. Numbering 96,000 across Tamil Nadu and validated through a comprehensive enumeration process, they face significant challenges. Despite being the backbone of urban WASH systems, they operate under hazardous conditions with limited access to personal protective equipment (PPE), irregular wages and inadequate healthcare. The survey revealed alarming trends: a substantial percentage of these workers reported chronic health issues due to occupational hazards, with minimal access to health insurance schemes or regular medical check-ups. The intersecting vulnerabilities of climate risks, WASH inequities, and the plight of sanitation workers necessitate targeted interventions, particularly through inclusive City Climate Action Plans (CAPs).

CAPs offer a framework for addressing WASH vulnerabilities in the face of escalating climate impacts. CAPs can integrate climate-resilient WASH infrastructure such as decentralized water management systems, adaptive sanitation technologies, and disaster preparedness mechanisms. The importance of these measures is underscored by the significant flood impacts observed in Chennai, where high inundation affected 31% of slums (1,251 settlements) and 7% of fisherfolk settlements (75 areas), with moderate inundation impacting an additional 46% of slums and 7% of fisherfolk settlements. These events highlight the urgent need for robust WASH interventions to mitigate the cascading risks of urban flooding. Chennai's experience provides compelling examples of how flood mitigation projects, rainwater harvesting systems, and eco-friendly sanitation technologies can align with broader climate goals. These interventions can minimize health risks by reducing water contamination, a persistent issue during and after urban flooding events.

A central aspect of these efforts involves the transformation of sanitation systems and the professionalization of CSWs. Through the Urban Management Centre (UMC)'s Technical Support Unit for the Sanitation Workers Development Scheme, substantial progress has been made in uplifting these workers. UMC's initiatives have equipped CSWs with modern sanitation technologies, protective gear, and training in health and safety protocols. For example, UMC's advocacy resulted in procurement of PPE, with recommendations for decentralized purchases by Urban Local Bodies (ULBs) using scheme funding. This approach ensures timely access to essential protective equipment while reducing centralized procurement bottlenecks. However, as climate change exacerbates challenges such as urban flooding, the need for climate-friendly PPE has become critical. These advanced protective gears are designed to withstand prolonged exposure to water and other flood-related hazards, enabling

CSWs to continue their work safely and efficiently during inundation events. As a result, the percentage of CSWs with access to proper PPE has risen significantly in participating ULBs.

Furthermore, UMC's capacity-building programs have emphasized health camps, skill development, and financial literacy to improve workers' overall well-being. The survey data indicated that over 50% of sanitation workers had never attended a health screening camp before these interventions. By addressing this gap, UMC has facilitated access to periodic health check-ups and insurance enrollments for a growing number of CSWs. These steps are vital in reducing the long-term health risks associated with exposure to hazardous substances during waste management.

Case studies from Chennai's urban slums illustrate the efficacy of linking WASH interventions with broader climate action. In one instance, community-driven rainwater harvesting projects in low-income settlements improved household water security by up to 40% during peak drought periods. Similarly, eco-friendly sanitation systems deployed in flood-prone neighborhoods reduced waterborne disease outbreaks by approximately 30% in the monsoon aftermath. Women-led WASH committees have played a pivotal role in these successes, organizing hygiene awareness campaigns and leading waste segregation initiatives that improved local health outcomes. These gender-responsive strategies underscore the importance of empowering women as agents of change within their communities.

Quantitative insights from the Sanitation Workers Development Scheme further highlight the transformative potential of linking WASH interventions to climate action. Enumerated data from Tamil Nadu's 649 Urban Local Bodies revealed critical gaps in existing systems. For instance, less than 30% of workers reported access to safety equipment at the time of enumeration. Post-intervention data show marked improvements, with over 60% of surveyed workers reporting access to improved facilities and training. Additionally, ongoing capacity-building efforts have empowered CSWs with climate-adaptive skills, such as operating mechanized desludging equipment, which significantly reduces manual handling risks.

These initiatives highlight the importance of institutionalizing inclusive WASH strategies in CAPs. Policy frameworks must prioritize adaptive sanitation technologies, worker welfare measures, and public-private partnerships to ensure sustainability and scalability. CAPs that explicitly address the needs of vulnerable populations, including informal settlers and CSWs, can foster urban resilience while promoting equity. For example, integrating CSW empowerment programs into municipal disaster management plans ensures that these essential workers are protected and equipped to respond effectively during climate-induced emergencies.

Chennai's journey demonstrates the viability of community-driven and policy-backed approaches in addressing WASH and climate challenges. The implementation of decentralized WASH solutions has not only improved service delivery but also reduced the vulnerability of at-risk populations. By incorporating robust disaster preparedness mechanisms, such as early warning systems and safe water storage facilities, CAPs can further enhance urban resilience. Concurrently, addressing systemic inequities faced by CSWs, through measures such as regularization of employment contracts and access to social security schemes, ensures a more inclusive and just approach to climate adaptation.

In conclusion, the intersection of WASH and climate resilience must remain central to the formulation of City Climate Action Plans. By prioritizing vulnerable communities and strengthening the role of CSWs, cities like Chennai can build sustainable and equitable urban systems that align with global climate goals. The Sanitation Workers Development Scheme provides a replicable model for integrating worker welfare with WASH improvements, demonstrating the potential of inclusive planning to create healthier, more resilient urban environments. Such initiatives not only address immediate challenges but also pave the way for long-term urban sustainability and social justice.

Gender gaps in water management: a case study and Pilot Project in Mukuru Kwanjenga Slums, Nairobi Kenya

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Kenya vision 2030 recognizes that Kenya is a water scarce county and therefore emphasizes water conservation and the prudent use of, for the limits available portable water. Nairobi City Water and Sewerage Company (NCWSC) is wholly owned subsidiary of Nairobi City Council and is mandated and responsible for the provision and management of water and sewerage services in Nairobi County.

Athi Water Works Development Agency (AWWDA) is charged with the responsibility of developing key water and sewerage infrastructure. NCWSC through its eight regional offices is responsible for providing clean, safe, easily accessible, reliable and affordable drinking water and sewerage services to the residents of Nairobi County; whose estimated population stands at 5.9 million people by 2022 according to Nairobi Integrated Development Plan – CIDP (2020 – 2022) among these population 60% of them live in the informal settlements. According to Amnesty International report roughly 2.50 million people live in the informal settlements of Nairobi, crammed into only 5% of the city's residential areas and just 1% of the land in the city. These residents suffer silently in accessing clean, safe affordable reliable and easily accessible drinking water despite huge water infrastructure development funded by Development partners like the World Bank, European Union, USAID among others, through the various Government Agencies like Athi Water Works Development Agenc; the private sector has contributed immensely towards supporting water services and infrastructure development like Safaricom Foundation, Cocacola Foundation,among others. Both the National and County Governments have as well supported water projects through CDF kitty. Corrupt practices thriving in the poor and lack of Community Ownership Strategy Intervention (COSI) is killing the sector silently, harming the poor communities, exacerbating inequality and reducing investments to wastes. Corruption has disproportionally impacted negatively the communities living in these informal settlements, eroding the trust between them and the water service providers in our case being Nairobi City water and sewerage Company -NCWSC, wasting funds and taxes. According to our door to door snap shop of funded operational and nonoperational WASH facilities in these settlements only 20% of them are operational the rest are either deserted, vandalized demolished and non operational; over 120 Number of community water boreholes fully furnished with masonry water kiosk and elevated water storage facilities have been drilled in Nairobi County, a small fraction of them nearly 20% of them are operational while the rest are nonfunctional. Huge water pipeline infrastructure development that has been funded by development partners through the Government have been vandalized, neglected and wasted; and water mafias / cartels taking charge of the system and enriching themselves through selling water expensively and selling illegal water connections. Communities watch in disbelief and despair as corruption take toll on water service delivery and provision becoming a major challenge to tackle; but there is light at the ed of the tunnel to end this menace. One practical example is community's resilience in fighting the vice in Mukuru kwanjenga informal settlements.

Communities living in Mukuru Kwanjenga an informal settlement in Mukuru slums of Nairobi. According to 2019, Kenya Population and Housing Census reports the population of Mukuru kwanjenga was 242,941 living in an area of 2.8 kms squire and a population density of 87,538. Currently the population is indeed high almost 300,000 people. These settlement in Embakasi South Constituency, almost 6 kms away from Jomo Kenyatta International Airport off North Airport road was a captive of water mafias / cartels, petty, grand and systematic corruption which killed water service delivery in the area, amidst the presence of NCWSC security team, the law enforcement units and the provincial administration, on the ground. Like any other informal settlement, Mukuru kwanjenga benefited and continues to benefit from developmenet partners like the World Bank, European Union, AFDB among others. Its in record that water infrastructure development projects including six community water boreholes fully furnished with each two water kiosks and elevated water storage tanks; 24 No. of masonry water kiosks; 15 No. of ablution blocks and sanitation blocks, 4 No. of biocentres; major 8 inche - water pipeline drawn from the water pipeline along Mombasa road and north airport road; the Non-revenue water was high as 80% far above WASREB 20% agreed rates; there was a hostility and animosity between the NCWSC security team and the water mafias/ cartels, who had taken the community hostage; corruption was rife in these settlement and in broad day light it had become a norm; no one dared to shout otherwise he / she will be executed; structure owners used to pay heavily for the commodity at the end of the month like kshs 50,000, this was the lowest figure; Institutions like schools were served with water by these water cartels and paid heavily like 80,000 per month; There were rampant cases of “free sex for water services” and most of the teenage girls got pregnant, contracted HIV/AIDS / STIS and others dropped out of school; families were unstable economically and lived in fear always due to changes in the pricing of the water by these water cartels; Kenya power was not spared, their power lines from the National Grid were hooked and the electricity illegally and carelessly tapped (sambaza) used to operate the water pumps, a phenomena which resulted to many deaths as a result of electrocuting and water borne diseases including cholera outbreak ; largely, life was meaningless to these community members.

Thanks to Eng. Gakubia, CEO WASREB; who launched Water Action Groups in the year 2012 and it was in the year 2019 when the impact of initiative was felt on the ground. Nairobi Water Action Group team jointly with grassroots community based Organizations, other stakeholders and Communities boldly, swiftly, wisely and strategically focused on the community ownership strategy rather that participation to bring everyone on board and leaving no one behind not even the physically challenged, the elderly, the youth, the young, women, institutions / schools, religious groups and leaders, the media, nyumba kumi elders, NCWSC team, water vendors, water mafias / cartels, CBOs, FBOs, law enforcement units and community groups and members.

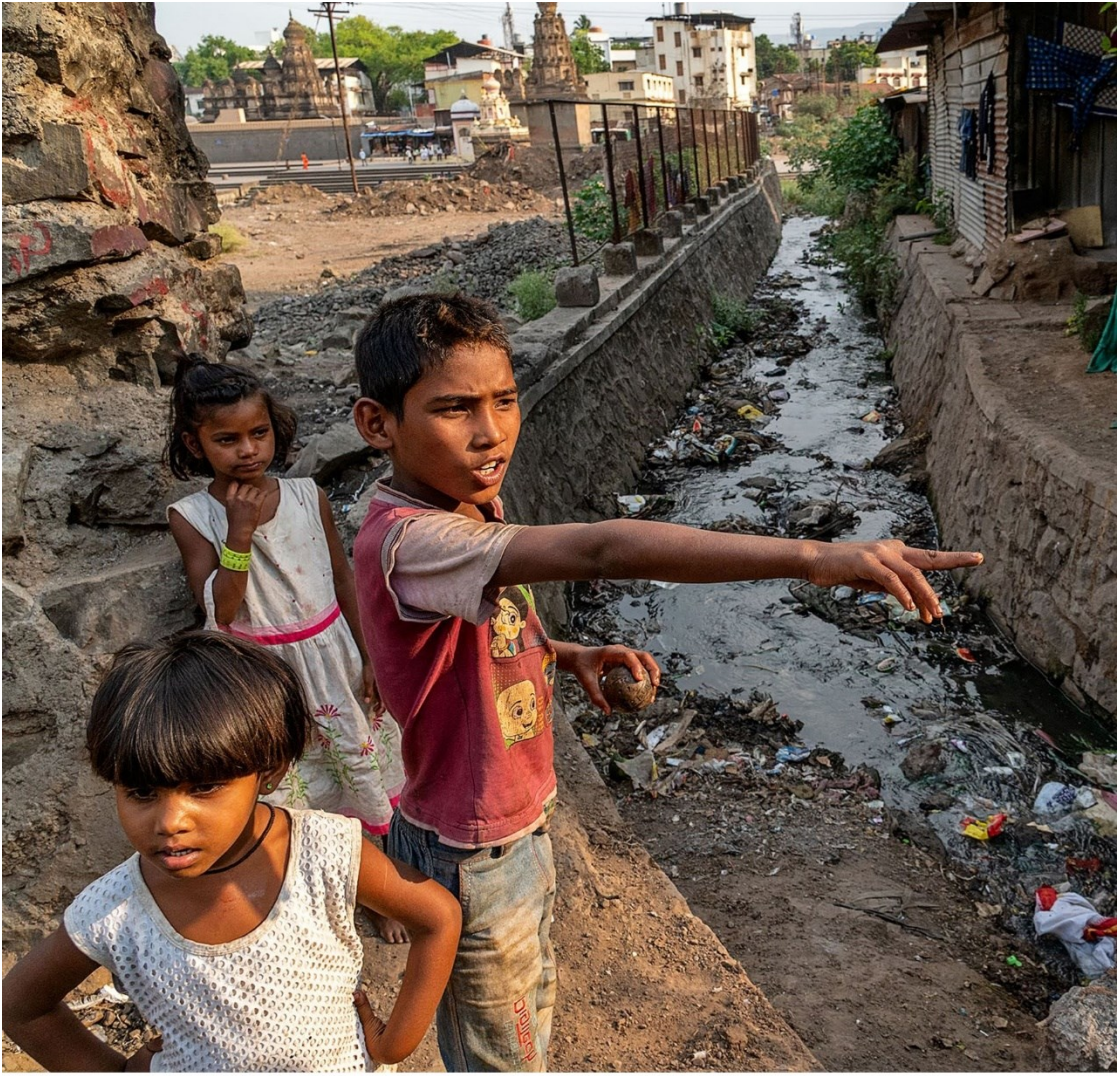
At first it was not easy, WASREB head office – WAG Coordination officer, Terry Micheni, was of much help to WAG members; in one case, a NCWSC security staff was interdicted following leaking vital information provided by WAG members on illegal water connections. Another incidence a powerful water mafia / cartel was arrested taken to court and fined kshs 100,000; it was not business as usual.

Community water meetings and dialogues which started with only five people, ended up being attended by hundreds of thousands pf residents demanding their right to water. Communities came together and appointed a Delegated Volunteer Community Water Working Groups (DVCWWGs) to work with the WAG members to spearhead their driven proposals and agendas. These group was purely established by the community to safeguard and report of any malice in the water services with the support of WAG members.

Results : - 1. The community as key beneficiaries were a happy lot because the water tariffs went down from 20/= per jerrycan to kes 3 – 5; they too had chances to apply for legally connected and metered water, 2. Water mafias / cartels menace died a natural death, most of the were transformed and benefited from legally sourced water through the water chambers constructed, 3. The Board of NCWSC transferred and sacked many of its staffs involved in corruption during that period, 4. The relationship between communities, water cartels now water vendors and NCWSC team significantly improved and regular community water dialogues and meetings were convened and the attendance was encouraging from these groups, 5.The revenue collections rose from 10% to 80% prompting NCWSC management to open a maji mashinani office in the area, 6. Non-revenue water which had recorded as high as 90% dropped to almost 20% after sealing all loopholes of illegal water connections and vandalism of water infrastructure, 7. 80% of the WASH funded community facilities like water kiosks, sanitation

blocks, Bio centers become operational after many years of abandonment and non-functionality, and 8. The management of the water services and infrastructure rested in the safe hands of the community and NCWSC, The community members were issued with a water chamber keys and another copy remained with NCWSC meter readers. The bar was set high for the corrupt and their agents to thrive and most of those water cartels left the sector peacefully, without intimidations.

The call for scaling up this Community Ownership Strategy Intervention – COSI, the only viable innovative strategy to fight head on corruption in the water sector is indeed required to be implemented in other informal settlements, marginalized communities and areas. The power of the people well deeply rooted in factual researched information can chat the destiny of water sector and make a difference. Supporting Nairobi Water Action Group who are independent, locally, registered Community based Organization is indeed the sure way. Water Action Group members are made up of volunteer citizens who are well conversant with community water issues they represent and live in. Currently we have a total of fifteen members though we were twenty-five but others dropped from being volunteers. These members sit in various Community based Organizations either as key founders, or committee members or just members. All these CBOs formed an umbrella membership Organization called Small water service providers association of Kenya. Our strength is drawn from Constitution of Kenya (CoK 2010), water act 2016, WASREB consumer engagement guidelines; Nairobi City County Based water bill 2017 and other local, regional and international instruments like the UN Charter for water and other human rights instruments. Our works involves around advocacy and awareness creation through digital platforms and physical presentations. Initially, we were very active and we were issued with passwords in the Maji voice platform, an innovative accountability tool developed in the year 2015 by WASREB, World Bank and participating licensed WSPs; to access complaints raised by consumers and communities; Each WAG member could each assign complaints related to corruption, non-supply of water, leaks, bursts, etc. From the system. During these period, the complaints rose from 46% to 94% due to the trust of WAG members in the system; but not all where happy, we were shut down and our passwords shit down as well.



Theme 3.2: Inclusive and Climate-resilient Sanitation Systems

Integrating Gender Equality and Social Inclusion into Uttarakhand's Sanitation Journey: Aspirational Toilets for Climate-Resilient WASH for All

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Achieving climate-resilient Water, Sanitation, and Hygiene (WASH) systems requires an inclusive approach that actively engages all members of society, including women, men, persons with disabilities, and marginalised groups. Access to sanitation is universally recognised as a fundamental human right, essential for health, dignity, and prosperity. However, despite policy progress under India's Swachh Bharat Mission-Urban (SBM-U), significant gaps persist in the availability of inclusive sanitation facilities for marginalised groups, including women, children, the elderly, transgender individuals, and persons with disabilities. This study examines the integration of Gender Equality and Social Inclusion (GESI) principles within the sanitation infrastructure of Uttarakhand, with a focus on climate-resilient WASH systems to ensure equitable access for all. The study highlights the synergies between the Sendai Framework for Disaster Risk Reduction and SDGs, underscoring that addressing GESI in WASH interventions is crucial to ensuring these global goals are met by 2030.

The National Institute of Urban Affairs (NIUA), in collaboration with Uttarakhand's Urban Development Department (UDD), conducted a comprehensive study on public sanitation facilities in the cities of Dehradun and Ramnagar. The study, grounded in Citywide Inclusive Sanitation (CWIS) principles, assessed gaps in public sanitation facilities, including the universal accessibility of toilets, the adequacy of menstrual hygiene provisions, and safety concerns. The research also involved the active participation of marginalised groups through surveys, key informant interviews, and focus group discussions to ensure that the voices of these communities were central in identifying infrastructure needs. Findings revealed significant deficits in inclusive provisions, with 60% of public toilets failing to meet the needs of diverse users, including persons with disabilities and other vulnerable groups. In response, to adequately address these findings, a framework is being developed by NIUA outlining guidelines for the construction of Accessible toilets, which are both inclusive (across the disaggregated groups of women, children and the elderly) and climate-resilient. This framework emphasises the integration of equitable planning, climate-resilient design features, such as rainwater harvesting and water-efficient technologies, and participatory processes that account for the unique needs of marginalised groups.

In alignment with SBM-U 2.0's emphasis on Aspirational Public Toilets, the study outlines a five-pronged approach to building an inclusive and sustainable sanitation system in Uttarakhand: 1) routine assessment of public sanitation gaps, 2) identification of unique user needs, 3) creation of inclusive provisions, 4) monitoring and evaluation, and 5) capacity building of stakeholders. The study's outcomes contribute to the broader goals of SDG 6 (clean water and sanitation for all), SDG 5 (gender equality), SDG 10 (reduced inequalities), SDG 13 (climate action), and SDGs 11 and 3 (sustainable cities and health), advancing the integration of gender equality, social inclusion, and climate resilience in sanitation planning and implementation.

Bridging Gaps: Climate Change, Sanitation Workers, and Resilience in Off-Grid Communities

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Despite global efforts to improve sanitation, significant gaps in infrastructure and service provision persist, particularly in the Global South. These challenges are further exacerbated by the escalating impacts of climate change, as highlighted through a case study of Alleppey Town in Kerala, an ecologically fragile coastal region. This research investigates the intricate relationship between climate change and sanitation services, focusing on the experiences of sanitation workers who bridge the gap between technologies and service delivery in off-grid towns where sewer systems are absent. Utilizing qualitative methodologies, including Focus Group Discussions and Key Informant Interviews, the study explores the implications of climate-induced environmental changes on sanitation work, livelihoods, and overall service delivery. In Alleppey, flooding, heavy rainfall, and other climate-related events frequently disrupt sanitation infrastructure and operations. Sanitation workers, both manual and mechanized, face heightened exposure to health risks due to pathogen proliferation in inundated systems and increased workloads under adverse conditions. The informal nature of sanitation work in this region, compounded by governmental neglect, intensifies these vulnerabilities. Workers often operate in hazardous environments, exacerbated by water scarcity and resource stress, further demonstrating the need for climate-resilient approaches to sanitation service delivery. The study identifies the critical role of sanitation workers in ensuring equitable access to sanitation services in vulnerable areas. By emphasising their dual role as frontline service providers and stakeholders impacted by climate change, the research connects sanitation challenges with broader sustainable development goals (SDGs). Specifically, it highlights the intersection of SDG 6.2 (universal access to sanitation and hygiene) and SDG 8.8 (promoting decent work and safe working conditions). The findings underscore that without prioritising the rights and safety of sanitation workers, the achievement of sustainable sanitation goals will remain unattainable. Recommendations from the study advocate for systemic changes, including capacity building and professionalisation of sanitation workforces to adapt to climate change. Improved training and adoption of decentralised, climate-resilient systems are crucial for addressing the twin challenges of service provision and worker safety. Additionally, strengthening the policy framework to integrate climate adaptation strategies with sanitation planning is essential to safeguarding both human and environmental health. Through its focus on Alleppey as a microcosm of broader coastal and flood-prone regions, this research underscores the urgency of addressing sanitation challenges in the context of climate change. By linking local experiences to global policy discussions, it provides a compelling case for prioritising sanitation workers and integrating climate resilience into sanitation strategies. The study ultimately calls for an inclusive, sustainable approach to sanitation service provision, one that places workers at the centre of planning and decision-making processes.

Localizing Plastic Action and Achieving Circularity through Youth, Children and Communities as Agents of Change

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The escalating plastic pollution crisis necessitates innovative and scalable interventions to address systemic inefficiencies within municipal solid waste (MSW) management frameworks. In response, a pilot intervention was implemented under the Maharashtra Urban WASH-ES Coalition supported by UNICEF Maharashtra, across three Urban Local Bodies (ULBs) in Maharashtra. Over a four-month period, this initiative facilitated the collection of 11.7 tonnes of plastic waste across 34 collection days, resulting in an estimated reduction of 40,950 kg in carbon emissions. This pilot served as a critical proof of concept, demonstrating the efficacy of localized circular economy models, particularly in smaller cities, while aligning with the environmental objectives of the Majhi Vasundhara Abhiyan (MVA) and Swachh Maharashtra Mission Urban.

Building on this preliminary exercise, a comprehensive assessment was conducted across 20+ cities in Maharashtra to analyze the MSW value chain through multi-stakeholder engagement, including municipal authorities, informal waste workers, and representatives from the private sector. This analysis identified critical challenges, including fragmented governance structures, limited integration of Extended Producer Responsibility (EPR), the underutilization of Public-Private Partnerships (PPPs), and insufficient inclusion of the informal sector in MSW systems. While frameworks such as the Swachh Bharat Mission (SBM) 2.0 and various national policies emphasize the importance of PPPs, their operationalization at the local level remains limited. The findings informed the design of the Localizing Plastic Action in Communities (L-PAC) project, a three-year initiative aimed at institutionalizing sustainable solid waste management practices in Pimpri Chinchwad Municipal Corporation (PCMC) and Satara Municipal Council (SMC).

The project framework is underpinned by three critical components:

Institutionalization and Governance: L-PAC focuses on strengthening institutional mechanisms to integrate sustainable practices into municipal governance structures. This includes adopting a differential implementation approach, characterized by a contribution model in PCMC—where interventions complement existing systems through ward-level pilots—and an attribution model in Satara, enabling city-wide implementation and urban-rural convergence in waste management. Enhanced governance will ensure long-term scalability and alignment with SBM 2.0 and Majhi Vasundhara Abhiyan priorities. Stakeholder-Centric Community Participation: Recognizing the multi-dimensional nature of MSW management, L-PAC emphasizes the active participation of Urban Local Bodies (ULBs), informal waste workers, Self-Help Groups (SHGs), private sector stakeholders, and local communities. Public-Private Partnerships (PPPs) are prioritized to address operational gaps, mobilize resources, and foster innovation. The inclusion of SHGs and youth ensures equitable participation and capacity building while promoting social and behavioral change through targeted awareness programs and educational initiatives developed under Majhi Vasundhara Abhiyan.Demonstration of Circular Economy Models in Waste Management: The project

includes piloting circular economy interventions, such as processing post-consumer plastic waste into value-added products, to showcase scalable solutions for sustainable waste management. These pilots aim to generate economic opportunities for marginalized groups, including sanitation workers and SHGs, while reducing environmental impacts such as plastic waste accumulation and open burning.

Advocacy and behavioral change activities form a cross-cutting component of the framework. Youth engagement is central, with their involvement extending to air quality monitoring using low-cost devices. This data will inform upstream advocacy efforts, culminating in the development of a Youth Clean Air Manifesto that outlines actionable, community-driven recommendations for reducing air pollution and its associated health impacts. This manifesto will be presented to municipal authorities to influence urban policy-making. Aligned with the priorities of SBM 2.0 and Majhi Vasundhara Abhiyan, the L-PAC project contributes to achieving multiple Sustainable Development Goals (SDGs), including 3 (Good Health and Well-Being), 4 (Quality Education), 5 (Gender Equality), 8 (Decent Work and Economic Growth), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 13 (Climate Action), 14 (Life Below Water), 15 (Life on Land), and 17 (Partnerships for the Goals). Tangible impacts include the diversion of plastic waste from landfills, reductions in open waste burning, improvements in air quality, and health benefits for urban populations. By bridging the gaps between policy, research, and implementation, the project demonstrates a robust pathway to achieving measurable environmental, economic, and social outcomes. The research-driven, community-centered approaches to solid waste management underscores the critical role of localized solutions in addressing global challenges related to plastic pollution and climate resilience.

Community-Driven Participatory Monitoring for Safely Managed Sanitation Services: FANSA's Experience on an Inclusive Approach to Strengthen Accountability

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Citywide Inclusive Sanitation (CWIS) ensures equitable access to safely managed sanitation, focusing on marginalized communities, particularly in South Asia, where rapid urbanization and inadequate infrastructure create significant challenges. Central to this approach is Community-Based Participatory Monitoring (CBPM), which engages local communities in monitoring, assessing, and improving sanitation services. CBPM promotes inclusivity by involving residents in identifying gaps, reporting issues, and co-developing solutions, ensuring services meet the diverse needs of all urban populations, especially marginalized groups, such as low income community; residents at informal settlement; sanitation workers; socially excluded community.

FANSA, through its national chapters across seven South Asian countries, has been implementing CBPM as part of its Rising for Rights (R4R) project. This initiative has led to significant community-driven changes by empowering communities to influence sanitation service delivery. By overcoming barriers like poor infrastructure and limited political engagement, the CBPM approach facilitates capacity building in leadership, advocacy, and communication with local authorities and service providers. This empowerment enables communities to successfully engage with local bodies, influencing the integration of their concerns into planning processes, thereby enhancing transparency, accountability, and responsiveness in service delivery. Through CBPM, communities can report sanitation issues and demand quicker resolutions, which improves service efficiency. This approach also encourages civic engagement, policy reform, and better service delivery, ensuring that sanitation systems are adaptable to challenges posed by urbanization, migration, and environmental changes. This promotes long-term sustainability in sanitation services. For example, in Bangladesh, communities advocated for the establishment of public toilets at Shreemangal Railway Station and improved waste management in tea gardens in the northeastern region. In Nepal, a new policy was introduced to protect sanitation workers and secure employment opportunities for transgender individuals in the sector. In Pakistan, a CWIS task force was created, involving government officials and community leaders, marking a historic milestone. Additionally, in Mardan City, the allocation of one million rupees in the local budget for safely managed sanitation signaled a significant policy shift. In Sri Lanka, a WASH Monitoring Centre was established to handle grievances related to water and sanitation, providing a platform for citizens to report issues, which are then communicated to service providers and followed up for resolution.

CBPM is a vital tool for advancing safely managed sanitation in South Asia. By involving communities in monitoring, management, and advocacy, CBPM fosters equity, accountability, and transparency, ensuring that sanitation systems meet the needs of all urban populations, especially marginalized groups. As South Asia continues to urbanize, integrating CBPM into WASH policies is crucial for addressing the challenges of rapid urban growth, inadequate infrastructure, and resource constraints. By transforming sanitation governance, CBPM provides a pathway to achieving inclusive, sustainable, and equitable sanitation services, ensuring that no one is left behind in

the pursuit of safe and accessible sanitation. The importance of these efforts is further supported by the findings of the Review of Sector Policies in WASH in South Asia: A Synthesis Report, which analyzed WASH policies across seven countries. While these policies emphasize equitable access to sanitation and the integration of sanitation into urban planning, significant implementation challenges persist. Rapid urban growth and informal settlements complicate effective service delivery, particularly in urban areas. The study identified the need for enhanced data collection, advocacy, and strategic planning to bridge the gap between outdated legislation and effective implementation. One of the key recommendations was the establishment of community mobilization units and the active promotion of community engagement. The recommendations underscored the importance of transparency, accountability, and community involvement in decision-making and implementation processes.

Thus, the presentation aimes at highlighting case studies of best practices from seven countries on how community involvement can enhance WASH interventions. By engaging communities in joint monitoring efforts and social audits, these practices allow for transparent reviews of activities, finances, and outcomes. Case studies from the region show the positive impact of regular social audits, empowering citizens to hold leaders accountable and ensuring efficient, ethical use of public resources. Furthermore, these case studies demonstrate how collective decision-making, which incorporates diverse community voices, leads to more inclusive and equitable outcomes, aligning with the community's needs and concerns. Ultimately, this approach fosters a culture of active participation, where communities drive positive change and build trust in public institutions, ensuring the long-term effectiveness and sustainability of WASH programs.

Unpacking the drivers of poly-crisis- A Case of WASH Service providers

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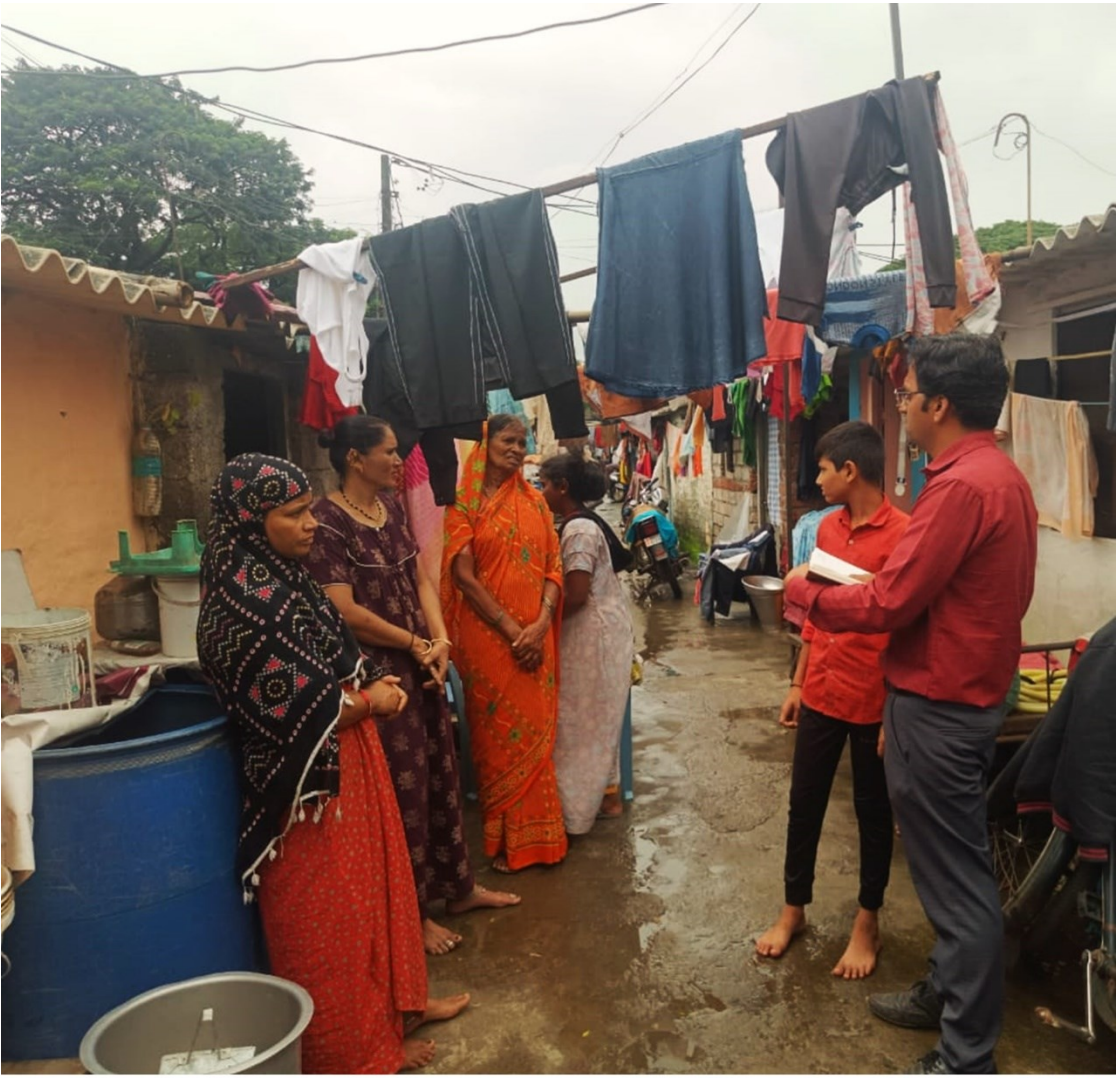
The term "poly-crisis" in global health affects marginalised populations in many ways, calling for good governance and leadership, accountability, and structural power dynamics. The present paper proposes to examine polycrisis from the perspective of a selected marginalised group- WASH service providers (WSPs)—in in context of South Asia. This is necessitated because of the thrust given to the service users to meet the development goals at the cost of the providers. A mixed-methods approach has been used to examine the issue, drawing from secondary and primary data on WSPs spread over selected metropolitan cities in India. About 250 study participants have contributed to the study.

Outbreaks of diseases such as COVID-19 strained healthcare systems and disproportionately affected the WSPs due to inadequate access to healthcare, congested living circumstances, and health inequities. They experience poor mental health outcomes, which are compounded by social variables such as poverty and prejudice and need to be examined in light of human weathering. Inequalities and disparities in health impact access to healthcare among marginalized populations, who frequently encounter obstacles like discrimination, exclusion, lack of health insurance, remote location, and financial limitations. Thus, health outcomes are lower for marginalized groups due to factors such as inadequate housing, food insecurity, unstable economies, and environmental hazards. Cleaning the sewers and drains is a hazardous job. The cleaners ensure a clean environment. Seasons are affected by climatic conditions and impact the drain and sewage flow. This accentuates the health risks of the service providers. Heatwaves and natural disasters are disproportionately experienced by marginalized populations due to socioeconomic deprivations.

Intersectional identities become relevant because of systemic racism, historical injustices, and cultural marginalization. Therefore, health disparities among marginalised communities are frequently exacerbated. A similar trajectory is evident in caste-based identities in South Asia. Comprehensive strategies that incorporate health equity into all policies and practices are needed to address the poly-crisis in global health and underprivileged populations. To achieve this, it is necessary to improve healthcare systems, advance inclusive governance, and provide marginalized communities with the tools they need to fight for their rights to fair health outcomes.



Theme 3.3:
Inclusive and Climate-resilient WASH for Vulnerable Population

Understanding Communitv based Usage of Water and Sanitation (WASH) in Informal Settlements in Bengaluru, India

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Bengaluru is increasingly being affected by the combined effects of climate change and rapid urbanization. Poor rainfall, rising heat, longer hot months and increased flooding are only a few of the impacts. The brunt is borne by people living in informal settlements. Since 2011, the city of Bengaluru has expanded dramatically. The population of the city has increased dramatically. Correspondingly, the city has more than 2000 informal settlements spread across it, with only 25% having access to some basic services. With little low-income housing available in the city, spaces between building sites, low lying areas, and 'vacant' lands have all been claimed by various actors to 'develop'. Most of these settlements are informal, with no tenure relationships and limited access to basic infrastructure and WASH. The settlements are constructed using materials like tin, asbestos, tarpaulin etc. which are heat absorbing. Homes in these settlements have little ventilation. Currently, climate responsive strategies in the city remain largely broad developmental strategies.

For a more nuanced approach to the climate change and developmental issues, some informal settlements have been assessed from a bottom-up level and with an ethnographic lens. The communities that live here have been studied in terms of their relationship with the settlement (how long they have lived there, how long they plan to stay, why do they live there), their relationship with the infrastructure of the settlement, both provided to them and developed by them (especially water and sanitation related), their investments in housing related infrastructure, their relationships with government and other power brokers, behavioral issues related their engagement with water and sanitation (WASH) infrastructure (especially post covid). Special focus has been on gender, diversity and disability related factors.

In this study, conducted for CURE (Center for Urban and Regional Excellence), we have conducted a broad-brush analysis of the community and behavioral aspects of the provisioning of and access to water and sanitation facilities in Bengaluru slums/ informal settlements.The study has focused on three-four settlements (selected for age, population type, location, diversity, typology etc.) in terms of site selection and settlement development, community engagement, behavioral change, participatory processes, information and communication dissemination, and gender, diversity and disability related issues as well as the resilience discourse (in terms of individual, household and community).The study will help improve the quality-of-service provision in slums/ informal settlements under the AMRUT program, especially for vulnerable individuals.

Designing as Though Retrofitting: A Bottom-Up Approach to Informal Settlements in the Global South

Author : Sheela Patel

Organization: Society for Promotion of Area Resource Centres (SPARC) | India

This paper explores the pressing issue of informal settlements in the Global South, where billions of people reside in habitats that are self-built, illegally constructed, and financed informally. Despite their widespread existence and significant impact on urban populations, the primary focus of social activists, researchers, and policymakers remains on land tenure, often neglecting the urgent need for improving these informal settlements. The paper delves into the realities of life in these informal settlements, highlighting the challenges of overcrowding, poor sanitation, and inadequate infrastructure. It emphasizes the urgent need to address the health and well-being implications of these conditions, particularly in the face of increasing climate change impacts.

To address these challenges, the paper proposes a novel approach: "Designing as Though Retrofitting." This approach involves a bottom-up, participatory design process that empowers residents to improve their living conditions. By working closely with communities, designers can develop innovative solutions that are both practical and culturally appropriate.The paper concludes by discussing the potential of this approach to transform informal settlements into vibrant and sustainable communities. By prioritizing the needs and aspirations of residents, we can create a more equitable and just future for all.

WASH Conditions and Public Health Status in Slums of Ahmedabad

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Inadequate water, sanitation, and hygiene (WASH) services often go unnoticed in cities, especially in informal settlements. These have a significant impact on disease prevalence in slums. Vulnerable communities are associated with these shortcomings, experiencing the most severe consequences on their general health conditions and overall well-being. Unimproved WASH conditions generally have adverse health effects, compromising the public health of the community.

This research aims to study these challenges faced by vulnerable communities through a series of interviews and questionnaire-based surveys both in slums and non-slum locations. It examines access to water, sanitation and hygiene practices amongst the selected slum locations in Ahmedabad and tries to relate to the prevalence of diseases among them. There is a significant difference between the slums and non-slum locations regarding the prevalence of water and vector-borne diseases. Hygiene practices are more preventive and precautionary in non-slum locations than in slums. It has been found that the lack of access to water and sanitation in the slums has resulted in a greater prevalence of diseases, and household responses to these diseases are of public concern. There is an urgent need to improve the WASH services for the slum locations in Ahmedabad through government initiatives, community engagement, and educational awareness.

Bridging Sanitation Gaps in Chennai: Inclusive Solutions for Climate-Resilient Urban Poor Communities

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Organization: Indian Institute for Human Settlements | India

Chennai, India's fourth-largest city, is home to nearly 5 million residents, with a significant portion living in underserved urban poor settlements (Census, 2011). Despite ongoing efforts to upgrade and resettle these areas, inadequate sanitation persists, exacerbating socio-economic and health challenges (Coelho, 2016; Diwakar, 2019). Addressing these issues requires incorporating the lived experiences of structurally excluded populations, such as transgender individuals and marginalised castes, into solutions for Water, Sanitation, and Hygiene (WaSH) access (Kaviarasu & Gladstone, 2015; Diwakar & Peter, 2016). Chennai's vulnerability to climate risks—including rising sea levels, increased precipitation, and flooding—further threatens its strained sanitation infrastructure (CEEW, 2021). The Chennai Climate Action Plan (CCAP, 2023) underscores the gravity of these risks, projecting inundation for 41% of the city's low-income settlements and highlighting slum housing vulnerabilities to heat stress and acute water scarcity. Annual floods disrupt WaSH services, posing immediate public health risks and long-term climate impacts from unmanaged wastewater and pollution. While previous research has focused on WaSH access in urban poor settlements (S. Mageswari & S. Gowtham, 2020; Diwakar & Peter, 2016), this study addresses a critical gap: enabling effective sanitation service delivery. By providing ground-level insights, it aims to enhance inclusive planning within the Greater Chennai Corporation's (GCC) climate adaptation framework, emphasising participatory approaches for vulnerable communities and identifying mitigation strategies for sustainable urban resilience.

Using a data-driven and mixed-methods approach, this study began with a review of literature and policies on sanitation service delivery in Chennai's slums, identifying key challenges and gaps. Urban poor settlements were categorised into typologies based on factors like tenure, population, geographic location, and sanitation infrastructure. Visual inspections at 35 locations led to the selection of eight diverse sites for detailed analysis. The research employed an app-based household survey (455 HHs, covering 10% of each location through stratified random sampling), in-depth interviews, focus group discussions with stakeholders, and transect studies to map spatial sanitation issues. The climate impacts on vulnerable populations, including urban flooding, heat stress, and water scarcity, were analysed. Triangulation of these data sources, along with institutional reviews and stakeholder dialogues, revealed critical insights into sanitation service availability, resilience, affordability, and quality.

Key Findings - Despite being declared "Open Defecation Free" in 2018, sanitation challenges persist: Access and Infrastructure Deficiencies - 1. Inadequate Toilet Coverage: 20% of surveyed households lacked Individual Household Toilets (IHHT), perpetuating open defecation, particularly during floods, 2. Sewerage Connectivity: 40% of households were not connected to the Underground Sewerage Systems (UGSS), with 16% disposing of wastewater directly into drains or water bodies, exacerbating contamination and emissions, and 3. Substandard On-site Systems: Nearly half of the on-site sanitation systems were poorly constructed or maintained, increasing risks of groundwater contamination and greenhouse gas (GHG) emissions due to irregular de-sludging practices.

Behavioural and Operational Challenges - 1. Solid Waste Mismanagement: Although door-to-door waste collection reached 70% of households, littering and open waste disposal persisted, contributing to 13% of total GHG emissions in 2018, and 2. Public Health Impacts: Service disruptions during floods led to mosquito breeding and disease outbreaks, affecting 60% of households.

Governance Shortfalls - 1. Climate Resilience: While flood-resilient infrastructure and community training initiatives were introduced, gaps in participatory planning and localised resilience strategies have limited their effectiveness, 2. Service Delivery: Weak grievance redressal mechanisms and inadequate stakeholder engagement hinder the quality and reliability of sanitation services, and 3. Lack of Monitoring and Adaptation: Insufficient data-driven monitoring systems and feedback loops have delayed responses to emerging challenges, particularly those linked to climate impacts.

Way Forward - To strengthen climate resilience in vulnerable communities, this study recommends: 1. Data-Driven Planning: Integrate urban poor needs into city-level climate and sanitation strategies, 2. Participatory Approaches: Involve stakeholders in co-creating solutions and validating findings, and 3. Targeted Interventions: Enhance WaSH infrastructure and service delivery, focusing on flood-prone and underserved areas. These steps, grounded in evidence and stakeholder engagement, offer a scalable framework for inclusive urban resilience planning, positioning Chennai as a model for cities facing similar challenges.

Strengthening Community-led Climate-Resilient WASH Governance in the Informal Settlements of Bhubaneswar and Jaipur

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Water, sanitation, and hygiene (WASH) are fundamental to public health, dignity, and well-being, yet, millions face inadequate access due to poor or absence of WASH infrastructures, governance gaps, and social exclusion based on identity, tenure and/or geographical locations. Marginalised groups, including women, PwDs, transgender individuals, and scheduled castes and tribes, are disproportionately affected, while climate change further adds one more layer of challenge through extreme weather events like floods, droughts, cyclones, and heatwaves that cause water scarcity and infrastructural failures, especially in the low-lying settlements; hence, climate-resilient WASH services are essential for long-term sustainability and in ensuring equitable access, promoting resilience to climate shocks, and empowering marginalised groups in decision-making processes.

This study examines the changes that occurred over the past seven years from its inception to evaluation between 2018 and 2024, covering access, community participation, governance structures, stakeholders' engagement, and policy implementation in Bhubaneswar and Jaipur, examining how inclusive governance models and participatory approaches have strengthened WASH access and resilience.

The intervention spanned over 87 wards and 280 settlements in Bhubaneswar (27 wards and 145 settlements) and Jaipur (60 wards and 125 settlements) over the last seven years in two-phased interventions. As part of the intervention, 270 members (including 210 women, 10 transpersons and 68 PwDs) are actively engaged in community operating structures like Community Management Committees (CMCs), Sanitary workers resource pools, Single Window Forums (SWFs) and Sanitation Sub-Committees (SSCs) established to facilitate the participation of marginalised groups. These community-led committees integrated local adaptation strategies into WASH services through participatory planning and decision-making, which includes data collection and validation by community members, institutionalising community-led processes for awareness, evidence-building and tracking of Saniclimiwall – a public dashboard, micro-planning, photo narratives, conducting participatory resource assessments, and review meetings which are central to ensuring sustainability.

A mixed-methods approach was adopted as part of the baselines (on access in 2019 and on climate impacts in 2023) and the endline evaluation (in 2024), combining quantitative household surveys with KIIs and FGDs in both cities. National and State-led policy documents, tracking of data through daily updated MIS and documentation of case studies and processes on climate-resilient WASH services were also reviewed to assess impact and effectiveness.

Findings reveal substantial advancements in access to basic and safe WASH services (JMP standards) and climate-resilient infrastructures and services (Rio Markers), engagement of community-led committees, leadership from the marginalised groups (GEDSI), and capacity building of the key stakeholders and community members. At the

end of 2024, it was observed that at the level of climate resilient WASH leadership, it encompassed 486 in Jaipur and 683 in Bhubaneswar through capacity-building initiatives. Access to drinking water increased significantly, benefiting 96.8% of individuals across both cities now have piped water connections compared to 62% in 2019.

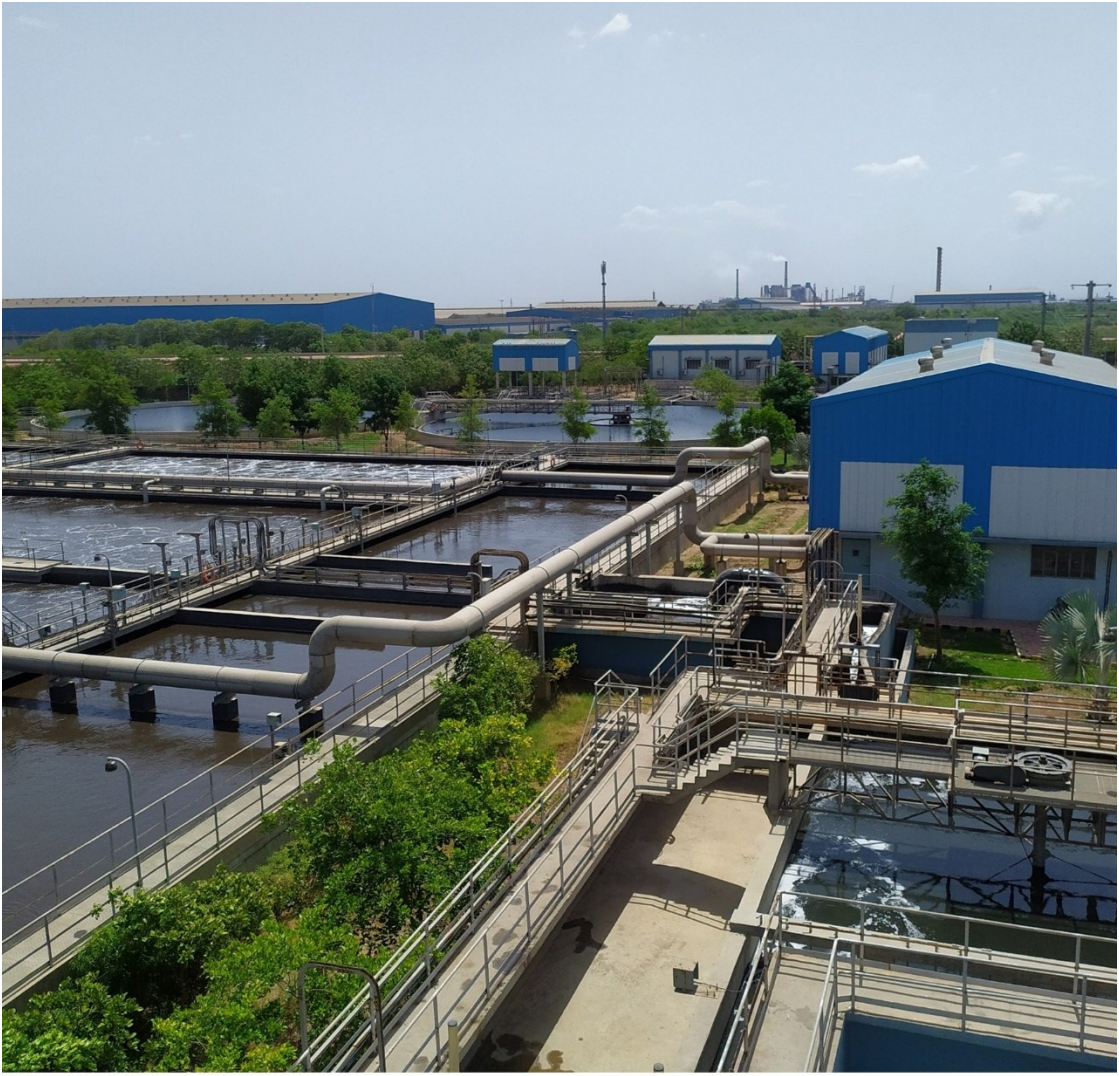
Marginalised communities through representational committees have led WASH governance, translating policies into action through participatory problem identification, solving and microplanning. Climate-resilient adaptations, such as raised toilet pits and resilient hand pumps, have addressed site-specific risks like waterlogging and flooding. Our intervention provided 31,866 unique individuals (8,141 households) with resilient access to WASH facilities during climate-related events like floods, cyclones, and heat waves. Data-driven decision-making has been strengthened through tools like the Saniclimiwall, which provides a public dashboard for tracking WASH progress and guiding systemic improvements. These interventions have resulted in a 56.4% reduction in waterlogging, a 78% improvement in toilet access for affected households, and a 45.1% decline in waterborne diseases alone in Bhubaneswar's Ward 5 (of 5840 households). This participatory model ensures city-wide WASH inclusivity by promoting trust, accountability, and resilience through active community engagement.

Toilet inclusion has also seen marked improvements. The proportion of households with individual toilets rose from 50% in 2019 to 89%, and open defecation declined notably in both cities. Also, about one-fourth of the services upgraded to climate-resilient and additionally, 50% of settlements now have significantly reduced waterborne and vector-borne diseases (from 77% reduced to 27%) through improved infrastructure such as safe containment and improved services such as periodic and mechanised desludging. Recent desludging (within the last six months) was reported by 37.2% of households in Bhubaneswar and 35.3% in Jaipur, indicating proactive desludging practices in both cities, with 67.6% of households using government desludging services. This is also reflected in other components such as drains and grey water management, albeit in a more gradual manner. All of the nine WASH committees in both cities now include members from transgender communities, PwDs, and SC/ST groups, ensuring a more inclusive governance framework.

The project's key achievement was enhancing WASH governance in informal settlements and bridging the gap between communities and the WASH system. This shift has been a game-changer in increasing access and enhancing accountability and participatory governance.

The endline evaluation concluded that the participatory, inclusive, and climate-responsive model has resulted in significant improvements in service delivery, leadership representation, and climate adaptation strategies in urban informal settlements. If we compare the progress in access to WASH services and governance structures between 2019 and 2024 with the initial gaps identified in the baseline studies, we find that processes that build trust and unleash behavioural change, along with a well-integrated social pact of rights and responsibilities, resulting in the following: greater community ownership of WASH services, increased accountability of service providers, enhanced climate resilience through localised adaptation strategies, and improved health outcomes through sustained sanitation practices.

Hence, moving forward, institutionalising these community-led committees' involvement in governance mechanisms, strengthening multi-stakeholder collaboration, and expanding climate adaptation interventions through community-led tools will be essential to ensuring the long-term sustainability of WASH services in vulnerable urban areas. And all Performance Assessment Systems (PAS) must integrate real-time community feedback mechanisms, data-driven decision-making frameworks, and policy-level commitments to GEDSI to ensure that WASH services remain inclusive, climate-resilient, and responsive to the evolving needs of urban informal settlements. Additionally, sustained financial allocations, such as those from the 15th Finance Commission, and the continued engagement of the NFSSM and allied networks, will be vital in scaling up inclusive, climate-resilient, and circular sanitation solutions across urban areas.



Theme 4.1: Innovations in Technology and Water Service Delivery

Rejuvenation of Water Tanks for Ecological and Socio-Economic Resilience in Kumbakonam

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Human development depends on water, a fundamental resource that has influenced civilizations for centuries. The diverse cultures of India have produced unique methods of managing water, particularly in semi-arid regions where tanks have historically boosted rural economies and irrigated over 4.8 million hectares in South India. The preservation of cultural legacy, rural development, and environmental sustainability all depend on these tanks. Due to silting, encroachments, poor maintenance, and an over-reliance on groundwater, tank irrigation's percentage of all irrigated land has drastically declined since independence, falling from 40% in 1950 to less than 17% now. India's traditional approaches to water management demonstrate a thorough awareness of the geography, rainfall, and community requirements of the area. Whether they were village ponds or temple-related, tanks had a variety of uses, including functional, decorative, and spiritual. For example, there are more than 39,200 tanks in Tamil Nadu alone, many of which are connected by cascade systems to provide for groundwater recharge and water storage. These buildings demonstrated the crucial connection between water and cultural history by supporting religious events like the Mahamaham Festival in Kumbakonam, which drew millions of devotees.

Rejuvenating these invaluable and crucial resources is the goal of recent initiatives in South India. Tank desilting, encroachment removal, and feeder channel revitalization are the main goals of restoration programs. According to studies, these initiatives can raise groundwater levels by two to five meters and boost tank capacity by up to 25%, thus increasing the amount of water available for daily usage and crops. These projects aim to restore groundwater, enhance environmental quality, and conserve cultural heritage by tackling urbanization pressures, pollution, and disturbed drainage systems. In order to strike a harmonious balance between tradition and advancement, this study emphasizes the urgent and essential need for sustainable management and conservation of water systems by bringing together ancient wisdom with modern techniques to harmonize tradition and progress. . In areas like Kumbakonam, tank restoration is crucial to restore ecological and socio-economic dynamism and ensuring resilience for subsequent generations.

Managed aquifer recharge using rainwater and treated used water for domestic water supply for a small town

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To understand and implement a managed aquifer recharge and reuse system for domestic water supply using local lake, rainwater and treated used water in a small town. The study was designed to understand both the quantity available and the quality of the shallow aquifer in Devanhalli town fed by the sweet water lake there. Wells were desilted , filter borewells dug in the weathered zone of the soil profile, pump tests carried out to determine the storativity and yield of the shallow aquifer and based on the quality of water found in the shallow aquifer water treatment plants designed to treat and supply BIS 10500 quality of water and integrate it with the towns water distribution network. Water balance studies were also carred out to understand the recharge potential in the overall shallow aquifer. The shallow aquifer currently gives a steady 640 kl/day of water to be treated and supplied to the town. Regular refilling of the lake with diluted treated used water from Bengaluru city does not impact the quality of water to make it unfit for treatment and water reuse. The understanding and reuse of shallow aquifer water is now being replicated in Devanhalli town itself at a larger scale of potentially 4 mld of water supply and is being tested out in many other town municipal councils and gram panchayats alongwith the Jal Jeevan Mission and Atal Bhujal Yojana .

Devanahalli is a small town located 35kms to the north of Bengaluru in the Bengaluru Rural District of Karnataka. It is known for the Kempegowda International Airport located nearby which has accelerated the growth of the town. The town has an area of 16.63sq kms, 23 wards and a population of ~39,000 and is entirely dependent on ground water for its needs. The primary source of water has been borewells and the depth has reached more than 1000 feet now. Since many borewells have stopped yielding, the Town Municipal Corporation has to dig new borewells often to meet the increasing water demand. There are around 130 borewells out of which 32 are not yielding anymore. It is estimated that the town has a total demand of around 2.66 Million Litres per Day @70 Litres Per Capita per Day, the standards as per the State Water Policy 2002, for its current population. Dependence on water tankers is not only at the private level. In some cases, even the TMC sources water from private water tankers. As the water supplied by the town has a high Total Dissolved Solids, people use Reverse Osmosis water dispensed in 17 select places paying Rs 5 for 20 litres for their drinking water requirements. Over the last few years, the Hebbal Nagavara valley project of the Minor Irrigation Department of the Govt of Karnataka, started pumping treated waste water into lakes around Bengaluru. When Devanahalli TMC desilted Sihineeru kere, the possibility of integrating the shallow aquifer through an old open well near the lake into Devanahalli's water supply became a potential opportunity. Biome facilitated revival of the well by cleaning and strengthening the structure with the anticipation that the well would start yielding. When the treated wastewater pumping started to Sihineeru kere, the well started yielding as expected with a capacity of around 240 KL/day. To draw more water from the shallow aquifer, two filter borewells (shallow borewells with slotted casing pipes and a gravel packing around the slotted pipes) were dug which increased the yield by another 120 KL/day.

The lake provides livelihood for a fisherman who rears fish here and is also visited by waders and birds like the cormorant and painted stork. Currently, the TMC supplies around 1200 Kilo Litres of water per day to the households at 32-35 LPCD. A Water Treatment Plant (WTP) including a 130 micron disc filter, a multi media with activated carbon filter, Ultra Violet disnfection and an online chlorinator, has been setup to treat the well water before it is integrated into the water supply system. The WTP ensures compliance of treated water with BIS 10500 standards and has been set up in the existing pumphouse and treated water is collected in the sump. The sump also receives water from the existing borewells, before it is pumped to the overhead tank as per the schema shown below. In the first phase the system was designed to pump and treat 240 KL/day of water. In the second phase the system was designed to treat and supply 400KL/day of domestic water for a total of 640 kl/day . The shallow aquifer water from the well requires much less energy for pumping and is therefore cheaper than the deep borewell water . It also has much less TDS and is therefore potable. This project was conceptualized and facilitated by Biome. However, successful execution happened due to contributions from key partners of the Ecosystem - TMC Devanahalli, EFI Foundation , Say Trees ,Well diggers community, Indian Institute of Science , Rotary Club and Carl Zeiss.

To make this ecosystem more robust, the following interventions are being planned

- Wetland at the inlet point of Sihineeru Kere to treat the water flowing into the lake
- Additional Filter borewells to increase shallow aquifer withdrawal.
- Biodiversity enhancement Intervention around the lake
- The cleaning of the channel called Kaluve, from inlet point of used water to the lake
- Lake bund stabilisation through plantation, connection of overflow weir to the nala, roadside planting and seating around the lake.

Last and probably the most important is to make this a learning laboratory and a case study that can be used in other towns and villages for reviving and integrating shallow aquifer to the water supply.

Sustainable Water Resource Management for Vulnerable Populations: Addressing Water Scarcity and Climate Resilience in Southern Bangladesh

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Co-Authors: Mostafizur Rahman, Global Water & Sanitation Center | Md. Abu Ragat Siddique, NGO Forum for Public Health

Water is an essential resource for sustaining life, promoting public health, and ensuring human dignity, forming the cornerstone of sustainable development. Despite significant global advancements in water access, millions, particularly in marginalized and displaced communities, remain deprived of safe drinking water. This study focuses on the water scarcity challenges in the southernmost district of Bangladesh, which exacerbates the vulnerabilities of both the host community and over 85,587 Forcibly Displaced Myanmar Nationals (FDMNs) residing in the Nhila Cluster, a focal area for the UNHCR. The region's unique coastal and hilly geography, compounded by aquifer depletion and saltwater intrusion, limits the availability of sustainable water resources, particularly during the pre-monsoon period (March to May), when water scarcity is most acute. The study investigates the current water supply systems and their operational challenges, with a focus on the reliance of FDMNs on scarce stream water during vulnerable months. To meet humanitarian standards of providing 20 liters of water per person per day for drinking, cooking, and hygiene, nine small-scale surface water treatment plants have been established. These plants, with a combined daily capacity ranging from 80 to 500 cubic meters, are strategically located near streams and reservoirs. However, the seasonal depletion of streams, especially during the dry season, undermines the effectiveness of these plants, resulting in intermittent water supply and heightened community vulnerability. To address these challenges, the study proposes a set of sustainable water resource management strategies, which include the exploration of alternative water sources, the construction of water storage infrastructure, and hydrological assessments of local water availability. The research also emphasizes the integration of climate-resilient approaches to water supply systems, aimed at ensuring consistent access to safe water, enhancing infrastructure resilience, and safeguarding public health in the region.

Following an extensive feasibility study, the research identifies five small- to medium-scale reservoirs with storage capacities ranging from 3,000 m^3 to 97,100 m^3, alongside the construction of 10 earthen dams, with storage capacities between 1,600 m^3 and 13,000 m^3. The study examines the challenges posed by tidal saline water and silt deposition on riverbeds, which complicate water resource management. In response, the dams are constructed using locally sourced clayey sand and reinforced with geotextile sacks to enhance structural stability and minimize seepage. This innovative design not only optimizes the use of local materials but also provides employment opportunities for local communities, contributing to socio-economic development while minimizing ecological impacts.

The study further evaluates the importance of efficient water transmission systems to ensure uninterrupted water supply. A network of HDPE pipelines has been designed to interconnect the storage reservoirs with the treatment plants, ensuring consistent water distribution throughout the year, even during the dry season. The integration of groundwater and saline water treatment plants into the transmission system enhances its resilience, ensuring equitable water access across the service area.Additionally, the research highlights several non-structural

activities, such as the establishment of a dedicated project team, bi-weekly stakeholder meetings, an online dashboard for water storage monitoring, and optimized operational scheduling to minimize water losses and improve overall system efficiency. The findings of this study provide valuable insights into the challenges and potential solutions for sustainable water resource management in resource-constrained, displaced populations. By exploring innovative, locally appropriate technologies and systems, this research contributes to the broader goal of achieving water security in vulnerable regions, promoting climate resilience, and ensuring equitable access to water for all.

Distributed Rain Water Harvesting (RWH) Nature Based – Shallow Aquifer Recharge – Use of Graded Gravel Pits (GGPs)

Author : G Ramkumar

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Been involved in propagating implementation of more than 2500 GGPs,spanning 20 years. Harvesting Rainwater through multiple graded gravel (blue metal) pits (GGPs).

Theme - Nature gives abundant Rain, The power of Soil to Retain Rain Water is Enormous, Let us Recharge the Extra Drop of Water to the Mother Earth, Our Planet would be Water comfortable for ever, and Let us join Hands and make a People's movement. Holistic approach - Mother Nature – the beauty of inter-play of: Soil, Water, Air, Plants – Trees, and Landscape. Our Attitude - the will to preserve, the Key

Soil is the largest reservoir of fresh water on our planet earth, Soil Holds 6 to 8 times freshwater of all river basins put together, Nature is abundant drain – Let us feed the soil with water, The soil is a living nurturing vegetation, Life for micro-organisms, enabling the positivity and reducing the impact of climate change, and magic of Rain & the power of Soil to Hold Water can be harness. Shallow Aquifer Recharge-well distributed by Provision of Cost-effective RWH : Graded Gravel Pits (GGPs) – can be done in open areas, lawns merging with landscape. Micro Pits within Storm water Drains for Rain Harvesting in Storm Water Drains even in concreted Plots, Water Recharge to the Soil is feasible through use of Shallow Wells. Leading to Sponge Plots, Minimum Structure, and Maximum Groundwater Recharge. The distributed RWH is fruitful at all Plots, at Elevated levels too assisting in Water recharge to the Soil, within the Plot , avoids Flooding, enables life to soil, soil strength, vegetation, greenery, Climate change, maintains fresh water, saline water curve, reduces saline water intrusion, saline water intrusion by capillary action, maintains lawns, avoids runoff and flooding in low lying areas and a Water Positive Model.

Graded Gravel Pits (GGPs) - I have been involved in propagating implementation of more than 2500 GGPs , so far. Harvesting rainwater through multiple graded gravel (blue metal) pits (GGP). The benefits of this are : design of pits is such that it permits both radial and longitudinal ingress of water as opposed to only longitudinal flow in conventional pits with concrete ring and hollow space leading to greater water percolation and it is cost-effective.

GGP has need to be popularised, answering a few points: 1. Unidimensional Storage perspective: Many have a myopic vision of collection and storage through artificial structures missing the need for leveraging the power of nature. They are oblivious of the fact that: Soil has an enormous capacity to hold water and is the largest reservoir of fresh water on earth holding 6 to 8 times the combined capacity of all river basins put together; on an average , a unit of soil contains 50% soil particles, 25% water and 25% voids, 2. A Holistic perspective- a necessity: - a. Mutual dependence between Soil and Water: The Water problem should be viewed holistically along with soil, which is a living being but which humankind treats as 'dirt'. "Soil is a living being" because it consists of living organisms- plants, animals, fungi, protozoa, earthworms, beetles and termites. bacteria etc. Soil breathes air and water to stay alive. A handful of soil contains millions of individual living organisms and there are more species in the soil than

above ground. Living soil is typically rich in organic matter and nutrients, which can hold water and support the growth and development of plants. b.Ability to recharge soil through storm water drains: Storm water drains are presently being utilised for throwing water from one area to another. Instead, if Rainwater is harvested in Storm water drains by putting Micro-GGPs, in a distributed manner, it will help to recharge the ground soil and only the overflow has to be led out. The GGPs filter the stormwater and recharge in all directions. This may be termed as Rain Harvesting Storm Water Drains (RH-SWD) which can help in soil recharge and reduction of flooding, and 3. Commercial perspective: Traditionally, consultants and contractors engaged in RWH have imbibed the structures syndrome wherein they advocate concrete structures for storage and holding water. Concrete structures increases the cost of RWH facility. Can we propagate the Cost effective RWH – the beauty of Shallow aquifer recharge.

Efforts in the propagation of GGP BASED RWH: 1. Awareness at all levels through Online / In person talks, Videos, articles, social media, World of Water (WOW) forums. The salutary impact on water table, water availability and reduced urban flooding, 2. Propagating Implementations at Industry, Complexes, Corporate Buildings etc., Rain Harvesting Storm Water Drains with Micro graded Gravel Pits within the storm water drain itself, very effective in concrete Urban Cities. Let us Join Hands for Water Comfort - for our Planet.

Teaching Water Supply and Sanitation Design in Engineering: A Pedagogical Experiment

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Co-Authors: Janki Jethi | Abhinav Arora, Gujarat International Finance Tec-City (GIFT)

Traditional methods of teaching water supply and sanitation design in engineering often rely on lecture-based courses emphasising hydraulics fundamentals and adherence to design standards. While effective in building foundational knowledge, this approach leaves limited scope for critical thinking and exploration. At CEPT University, a studio-based pedagogy was introduced in the undergraduate civil engineering program in 2016, offering an experiential learning environment through real-world projects. This innovative approach was applied to the design of water supply and sewerage networks, with three repetitions of the studio course completed to date. In the studio, students were assigned individual wards in diverse contexts, such as Junagarh (with significant elevation differences exceeding 30 meters) and small towns in Gujarat (with flat terrains of less than 5% slope). Site visits facilitated data collection and condition assessments of existing infrastructure. Concurrently, foundational concepts of hydraulics and design standards were delivered through lectures, expert sessions, and exposure visits. The first iteration emphasized manual design using Excel to reinforce hydraulic principles. In subsequent iterations, students modelled current water supply and sewerage systems to assess their adequacy for a 30-year horizon (2057) on software like WaterGems and SewerGEMs. Designing for a 24-hour continuous water supply revealed interesting results. In some towns, current storage capacities exceed future needs, revealing overdesigned systems. However, the existing networks struggled with increased demand and reduced pressure. Students then reimagined these systems, optimizing storage facility locations and network layouts. They challenged traditional CPHEEO (Central Public Health and Environmental Engineering Organization) standards, such as minimum pipe diameters and pressure management strategies for undulating terrains. Similarly, designing sewerage networks for small towns was a challenge, especially in flat terrains. With low-density areas in the present condition, maintaining self-cleansing velocity at the initial peak became an issue. The students, therefore, explored innovative sewerage design approaches like small bore solids-free sewers with lesser gradients for flat terrains to address challenges like maintaining self-cleaning velocities and controlling excavation depths. Key insights included the impact of land constraints on infrastructure siting, such as suboptimal locations of elevated storage reservoirs and sewage treatment plants, which increased costs and reduced performance. This pedagogical experiment demonstrated that studio-based learning fosters critical thinking, technical expertise, and adaptability in students. By engaging with real-world complexities, students mastered design principles and learned to question standardized practices and accommodate site-specific constraints. The findings underscore the need to revisit design standards like those of CPHEEO, particularly for challenging terrains and resource-limited contexts. The experiment highlights the potential for studio-based pedagogy to bridge the gap between academic instruction and professional practice, equipping future engineers with the skills and mindset required for sustainable and context-sensitive infrastructure design.

Theme 4.2:
Innovations in Technology and Sanitation Service Delivery

Sustainable Management of Emerging Contaminants in Wastewater: Monitoring, Governance, and Advanced Treatment Technologies in the Global South

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Co-Authors: Ligy Philip, IIT Madras

Managing emerging contaminants (ECs) in wastewater is a critical challenge for the Global South, particularly in countries like India, where over 38 billion liters of wastewater are generated daily, with 70% remaining untreated. Studies report pharmaceutical residues up to 10 µg/L and PFAS exceeding 100 ng/L in surface water, far surpassing permissible limits. Despite government spending of ?60,000 crore ($7.2 billion) annually on water treatment, only 30% of treatment plants in India are equipped to address ECs effectively.

This study investigates the gaps in EC monitoring, governance, and financing, alongside the application of advanced and hybrid treatment technologies such as membrane bioreactors, electrochemical reactors, and plasma-based systems. These technologies demonstrate removal efficiencies of 85-95% for ECs, but deployment is limited by high costs (?5-10 crore per unit) and operational challenges. Quantification efforts remain sparse, with 40% of water samples exceeding limits for pharmaceutical residues and 25% for other major ECs in Indian river systems.

The research proposes a scalable framework for EC management, focusing on improved monitoring systems, strengthened regulatory oversight, and increased investment in advanced treatment technologies. Key recommendations include fostering public-private partnerships and aiming for a 50% reduction in untreated wastewater by 2030 and a 25% decrease in EC contamination by 2035. This work provides a roadmap for sustainable wastewater management and enhanced public health in developing economies.

Resilience of Container Based Sanitation

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The resilience of sanitation has become a topic of great interest in the last 2 years. As very little climate funding reaches sanitation, new guidance on sanitation has recently been published as an annex to the Green Climate Fund's Water Project Guidelines, better defining what climate-resilient is sanitation and what can be funded. A landscape study published two years ago (Willetts et al 2022) has highlighted the need for more evidence of what climate-resilient sanitation can be like and how it can be deployed. Yet we need more documentation and evidence of which sanitation approaches can increase the resilience of both sanitation systems themselves and of communities. Container Based Sanitation (CBS) is a sanitation service well suited to a range of hard-to-reach contexts where installing conventional options such as sewers, septic tanks, and pit latrines can be challenging. CBS features toilets with a small waste container that is frequently sealed and safely collected, so that waste can be safely managed, usually producing circular economy byproducts. CBS has been recognised as a safe sanitation option to achieve SDG 6.2 by the World Health Organisation. As CBS does not require digging, it has found a niche in many hard-to-reach or underserved contexts, where few safe options exist: densely populated informal settlements, refugee or transitional settlements and areas with rocky ground, unstable soil conditions, high water tables, hills, limited water, or frequent floods. While evidence has already been published on other aspects of CBS such as climate emissions, cost-effectiveness and scaling barriers, one of the key gaps in published evidence, in a world increasingly impacted by the climate crisis, is the resilience of CBS. This includes resilience to floods, water scarcity, droughts and hurricanes as well as to civil unrest. This study aims to demonstrate the resilience and vulnerabilities of CBS. Data collected through a longitudinal smartphone study in Kenya, South Africa and Peru compares how CBS users and non CBS users coped while experiencing shocks.

Focus groups have been conducted with CBS providers showed that CBS has unique resilience advantages. For example, as CBS units are easily movable they can be moved out of floodwaters, to avoid the contamination with human waste that stems from overflowing septic tanks or pits. After the floodwaters subside the toilet can be moved back and used again safely. Most CBS toilets use little to no water, providing an advantage in water-scarce areas and during droughts. And CBS operators are uniquely skilled to navigate informal settlements for the frequent collections, helping them to remain operational during crises.

Unveiling the Potentials of the plant Panicum maximum in vertical subsurface flow constructed wetland in a humid urban sub-Saharan environment

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In many cities of sub-Saharan African countries, the situation of sustainable wastewater treatment using local technologies that required low maintenance and less energy is still missing or at early stage development in a looming climate conditions. This study evaluated the effectiveness of a local plant species Panicum maximum and compare to Paspalum polystachyum removal capacity, in enhancing the removal of Ni during wastewater treatment within microcosm reactors. As reseach question considered: which local plant species can be tested and used for the effective design of wastewater treatment facilities? what are the performances of Panicum Maximum in this purpose compare to Paspalum polystachyum? The experimental setup consisted of reactors (cylinder-shaped tanks) composed of different sizes of gravel, simulating the vertical subsurface flow constructed wetland (VSSF CWs) beds configuration, at the Métiypkwale campus of the University of Ebolowa, Cameroon. A total of eight pilot-scale units were used in a green house, with each plant species tested in triplicate, while one unit was used as non-planted (control) for each plant. Over a 3-months period, the units received monthly loadings of wastewater artificially polluted with Ni. Monthly plant and wastewater samples were collected from the VSSF CWs. The inlet concentrations were 1,191±0,003 mg/l for each reactor. Plant and water samples were pre-treated in the laboratory, digested using diacid and their Ni content were determined using atomic absorption spectrophotometer after filtration. The results showed the superior efficacy of planted beds compared to control beds, attributing this enhancement to the presence of vegetation. Therefore, the output concentrations in the unplanted system were 0.0215mg/l compare to planted bed with Panicum maximum that was 0.044 mg/ l and 0.043mg/l for the system planted with Paspalum polystachyum as all outlet concentrations were <0.2mg/l (WHO admissible level). The unplanted system had a purification performance of 94.0%, while the system planted with Panicum Maximum was 92.5% and 93.3% for the system planted with Paspalum polystachyum. The statistical analysis revealed that there was no significant difference between the purification performances of the two tested plants (pvalue < 0.05). These findings highlight the potential of Panicum maximum, a newly tested species, for application in constructed wetlands, emphasizing the need for dedicated research on this species.

Optimisation of Existing Resources for Sustainability of Used Water Management in Maharashtra through Urban Rural Convergence and upgradation of existing facilities

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The Sustainable Development Goals (SDGs), particularly SDG 6, emphasize universal access to safe sanitation and the reduction of untreated wastewater. In India, where centralized sewerage systems are limited, the Swachh Bharat Mission (SBM) promotes a combination of centralized sewerage and on-site sanitation systems, such as septic tanks and pit latrines. However, these systems require effective Fecal Sludge and Septage Management (FSSM) to ensure safe sanitation, particularly in small towns and rural areas. Before 2019, Maharashtra faced significant challenges in FSSM, including inadequate infrastructure, untreated waste discharge, overburdened urban and peri-urban systems, operational inefficiencies, and issues of overall sustainability. To address these challenges, the Urban Development Department (UDD), Government of Maharashtra (GoM), issued a directive in November 2019 mandating all Urban Local Bodies (ULBs) to construct Fecal Sludge Treatment Plants (FSTPs). By 2021-22, approximately 227 new FSTPs were established across urban Maharashtra. However, due to the low frequency of desludging household septic tanks, many FSTPs experienced negligible utilization rates. Additionally, cities faced challenges such as sewer and pumping station overflows caused by daily dumping of faecal sludge from desludging vehicles, leading to severe outbreaks of waterborne diseases in 2019 and 2021. To address these challenges, Maharashtra adopted a holistic approach combining policy support, community participation, technological interventions, and capacity building. A preliminary feasibility assessment of 141 urban FSTPs identified clusters with unutilized capacities, highlighting opportunities for Urban-Rural Convergence (URC). At the same time, in 2021, rural Maharashtra lacked infrastructure for managing faecal sludge. To tackle this, GoM and the Secretariat of the Maharashtra Urban WASH and Environmental Sanitation Coalition (Maha-UES-C) supported by UNICEF, Maharashtra conceptualized URC in FSSM as a sustainable, decentralized solution. Maharashtra's approach, unlike other states, is ULB-led, leveraging existing urban FSTPs to treat waste from nearby rural areas within a 10-15 km radius. This minimizes infrastructure duplication, optimizes O&M costs for FSTPs and desludging vehicles, and enhances sustainability. A pilot model implemented in Indapur, Pune, involving one ULB and 12 Gram Panchayats (GPs), successfully demonstrated resource optimization and institutional collaboration, with refurbishment of the FSTP emerging as a key enabler. Similarly, co-treatment of faecal sludge at Sewage Treatment Plants (STPs) was successfully demonstrated in Sangli Miraj Kupwad City Corporation, where faecal sludge was treated alongside sewage, leveraging existing infrastructure to minimize operational costs and enhance resource utilization. These pilot projects highlighted a win-win outcome for urban and rural governments, local stakeholders, and service users. URC reduces the need for new treatment facilities, leading to lower capital and operational costs, and achieves economies of scale by reducing desludging charges per trip. URC offers significant savings in lifecycle costs, reduces capital investments in new rural FSTPs, and alleviates the O&M cost burden on the local bodies. Furthermore, it enhances revenue generation, positioning FSSM service delivery as a financially sustainable solution for ULBs. Following the pilot, a detailed feasibility assessment was conducted across 53 clusters in 11 districts, covering urban FSTPs and nearby rural sanitation systems. The findings revealed persistent challenges

such as irregular and insufficient fecal sludge loads, design limitations, revenue generation issues, and barriers to reusing outputs. Despite these challenges, proactive ULBs demonstrated enthusiasm for implementing innovative solutions. The study underscored the potential to leverage existing data on FSSM infrastructure, urban FSTP capacity utilization, and rural sanitation systems to scale URC in Maharashtra.

The initiative to scale URC is being implemented in partnership with the Water Supply and Sanitation Department (WSSD) and the UDD. Six additional clusters have been identified for demonstrating URC models, designed to suit unique institutional and operational contexts. These include diverse implementation models such as ULB-led, SHG-led, Private Operator-led, and multi-stakeholder approaches. Key insights from pilots emphasize the need for institutional frameworks, FSTP refurbishment, sustainable O&M practices, inclusion of private sector desludging services, and viable revenue models for long-term success. To support implementation, Maha-UES-C has developed innovative tools, including a refurbishment cost calculator, desludging cost calculator, a web-based dashboard, and a toolkit for urban-rural and rural-rural convergence. Capacity-building initiatives, supported by WSSD and UDD, have strengthened the capacities of local officials and stakeholders. This initiative demonstrates a scalable model for optimizing resources and achieving sustainable FSSM, aligning with national sanitation goals and SDG 6. Maharashtra's approach offers a replicable framework for integrating urban and rural efforts to build resilient sanitation systems, delivering environmental and public health benefits across diverse contexts. Currently, Maha-UES Coalition is collaborating with both UDD and SWSM, GoM, to scale up URC in FSSM across more than 100 clusters, further solidifying Maharashtra's leadership in sustainable used water management.

Integrating Institution Building and WASH Interventions: Lessons from a Network Governance Initiative for Sanitation in Kerala

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This study examines a network governance initiative aimed at addressing the sanitation and water pollution challenges in Alappuzha, Kerala. The initiative, driven by the Canal Rejuvenation Project (CRP), sought to bridge critical capacity gaps in addressing sanitation problems through decentralized and participatory sanitation planning. The project aimed to address the need for reliable data for assessing the water and sanitation situation in small towns by leveraging academic expertise, participatory mapping, and multi-stakeholder collaboration. One of the main activities of this project was the development of tangible and intangible interventions to address sanitation challenges, mitigate environmental pollution and improve public health outcomes. This study focuses on two such interventions: institution building and the implementation of a Decentralized Wastewater Treatment System (DEWATS). This study, a part of my PhD research employed a qualitative case study approach with methods such as key stakeholder interviews, participant observation and focus group discussions. This design enabled an in-depth exploration of the socio-political dynamics and institutional barriers influencing the project's trajectory and outcomes.

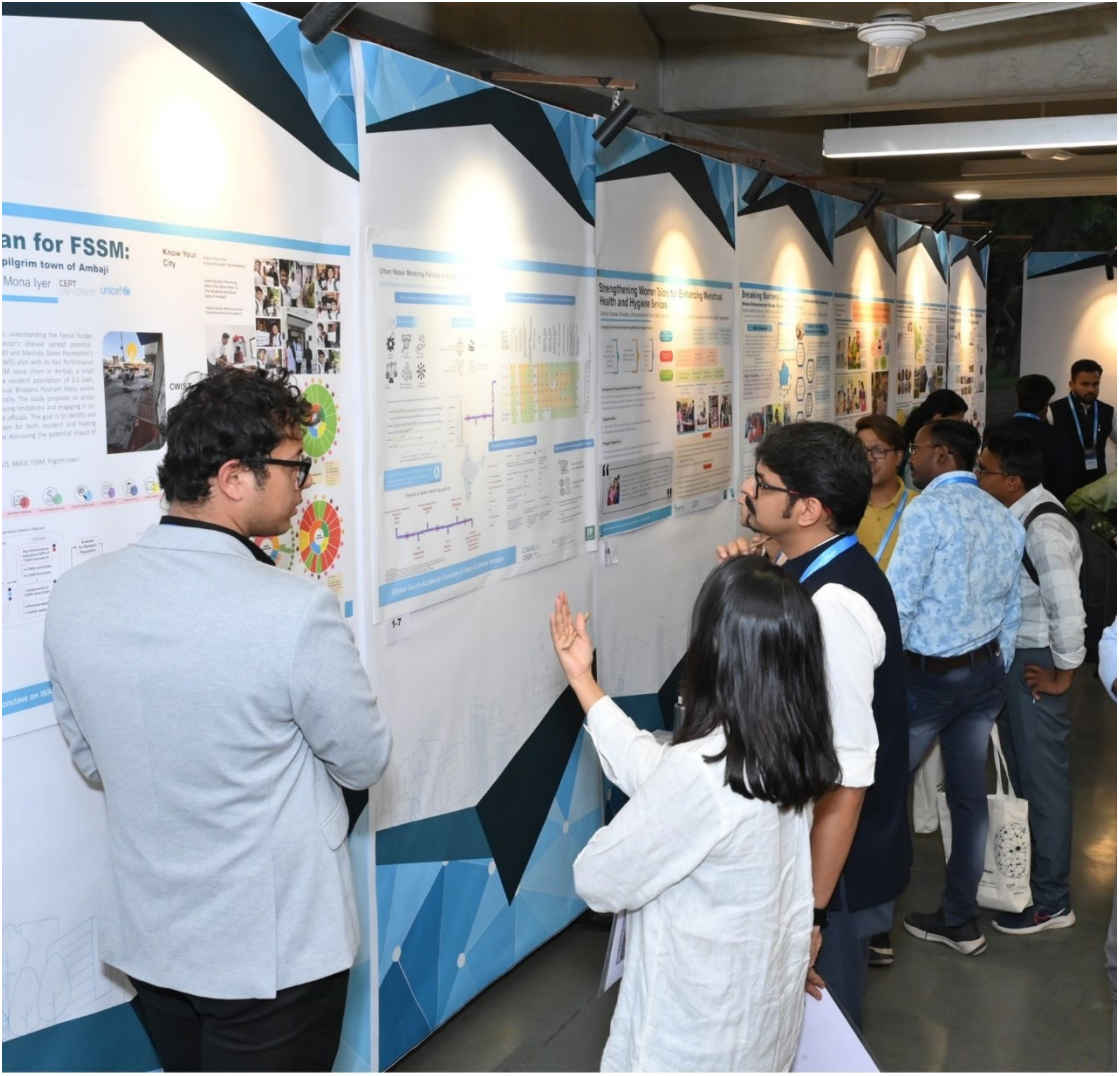
Drawing from the results and insights of a series of surveys and studies conducted during the initial phases of the project, several sites were identified for the design and deployment of context-specific interventions. One of the selected sites was a ward called Chathanad. The first intervention proposed at Chathanad was Institution building, which was centered on the formation of Canal Shed Committees (CSCs) to foster community ownership and participatory governance. These committees were designed to enhance accountability, establish norms for canal conservation, and facilitate local engagement. The second context-specific intervention by CRP was the decentralized wastewater treatment system (DEWATS) for the most marginalised colony (Municipal Colony) in Chathanad ward. The intervention involved constructing household toilets, a centralized underground pipe network, and a Decentralized Wastewater Treatment System (DEWATS), alongside aerobic composting units to manage solid waste. Apart from addressing the problem of sanitation and solid waste management, these interventions have climate impacts as they mitigate greenhouse gas emissions and promote circular waste practices.

However, the study reveals that institutional and socio-political barriers significantly impeded the long-term sustainability of these efforts. In the case of institution building, despite initial successes, such as active reporting of violations, the institutionalization of CSCs faced significant challenges. Political resistance, fragmented community dynamics, and a lack of clear governance structures hindered their sustainability and long-term impact. Partisan politics and fragmented governance structures also emerged as critical obstacles. The adversarial relationship between state and municipal governments, compounded by shifting political dynamics, influenced stakeholder engagement and project priorities. While awareness programs and citizen science initiatives temporarily mobilized residents, the lack of sustained engagement and unclear committee roles hindered long-

term participation. The reliance on informal mechanisms and elite-driven efforts limited the inclusivity of the governance process, disproportionately excluding marginalized voices. Consequently, the lack of an inclusive governance framework led to diminished community ownership and a reversion to previous practices, such as waste dumping into canals. Similarly, in the case of the DEWATS plant, institutional inertia, characterized by bureaucratic delays, outdated administrative practices, and hierarchical decision-making, prolonged the implementation timeline. For instance, delays in sanctioning funds, and inefficiencies in project approval processes underscored systemic governance challenges. These delays were further exacerbated by the reluctance of key administrative actors and the turnover of personnel, leading to knowledge gaps and further slowing project execution.

The findings reveal the potential and limitations of combining institution building with technical interventions in addressing sanitation challenges. While the DEWATS system effectively mitigated wastewater contamination and improved health outcomes, its long-term success depended on robust institutional support and community participation. Despite the failure of the institution-building process, it was observed that Municipal Colony residents took ownership of the DEWATS system. This sense of ownership can be attributed to two key factors: the presence of tangible infrastructure for waste management, which inculcated a sense of responsibility, and the municipality's decision to employ two of the residents to maintain the plant, further incentivizing their engagement.

This research underscores the importance of integrating participatory governance mechanisms with technical solutions to achieve sustainable outcomes in small-town sanitation contexts. The dual focus on institution building and DEWATS implementation offers valuable insights into the complexities of network governance, emphasizing the need for transparent, inclusive, and adaptive frameworks. By addressing both the technical and social dimensions of sanitation challenges, this study contributes to the broader discourse on urban environmental management and participatory governance, providing actionable lessons for policymakers and practitioners.



Poster Presentations Abstracts

Status of water, sanitation and hygiene in the Nepalese context

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Co-Authors: Anil Aryal

Water, Sanitation, and Hygiene (WASH) remain critical components of public health and sustainable development in Nepal. Thus, the constitution has recognized clean drinking water and sanitation as fundamental rights. Despite notable progress, still faces significant challenges in ensuring access to safe water, adequate sanitation, and hygienic practices for its population in the country. In this paper, we aim to explore the status of WASH in Nepal. Nepal has shown promising improvements achieving 19% coverage of safely managed water supply services, providing basic water supply services to 58% of the population with an 88% system coverage. Additionally, 5% of wastewater is being safely treated, and 61% of toilets meet the criteria for safely managed services as per the Joint Monitoring Programme (JMP) indicators. Over 80% of the population now has access to water, soap, and a designated handwashing area to promote hygienic behavior. Sanitation has seen progress as well, with over 95% of households reporting access to improved sanitation facilities. The government's "Open Defecation Free" (ODF) campaign achieved notable success in recent years, yet the sustainability of this achievement remains uncertain. Hygiene practices in Nepal are variable, with only around 70% of households reporting regular handwashing with soap and water, a figure that fell below required standards during the COVID-19 pandemic. Educational initiatives and infrastructure improvements are needed to promote lasting behavioral changes. Addressing WASH issues in Nepal requires integrated efforts, encompassing infrastructure development, policy reforms, and community-based initiatives that engage local populations in sustainable water management and hygiene practices. Further, the status of the WASH in the country will guide the relevant stakeholders in mapping the area that the government (federal, provincial, and local) should target in their plans and policies. By targeting these areas, Nepal can work towards meeting Sustainable Development Goal (SDG) 6, ensuring universal access to safe water and sanitation by 2030, and improving health, dignity, and resilience across the country.

Urban Storm Water Management: Quantifying Stormwater Reuse Potential in Darjeeling

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Ridge towns in the Himalayas, including Darjeeling, have been grappling with chronic water scarcity exacerbated by limited natural water sources, steep topography, rapid urbanization and the impact of climate change. The situation is further aggravated by a significant influx of tourists, placing additional pressure on the already constrained water supply. In Darjeeling, residents face acute water shortages, often managing with a mere 10-20 liters per capita per day (LPCD), far below the Government of India's guidelines of 135 LPCD for sewered towns and 70 LPCD for non-sewered towns.

Despite receiving an average annual rainfall of 3,092 mm over 126 days, stormwater remains an underutilized resource in Darjeeling. This study addresses two critical questions: (1) How much stormwater can be harnessed monthly from each of the town's seven sub-basins? and (2) Can this harvested water sufficiently meet the town's water demand?

Using the Soil Conservation Service (SCS) Curve Number method and analyzing 35 years of daily large rainfall data, the study quantifies monthly stormwater runoff across the sub-basins. Results reveal that during the monsoon months (June to September), stormwater runoff can exceed daily water demand by 3.5 to 5 times, potentially supplying up to 60 MLD, compared to the town's daily requirement of 12 MLD. However, from February to May and in October, stormwater availability drops significantly, with runoff ranging from 0.049 MLD to 7.6 MLD, insufficient to fully meet demand but capable of supplementing existing supply. In the dry months of November to January, stormwater runoff is negligible, highlighting the need for effective storage and management of excess monsoon water to bridge the supply gap during lean periods. This study underscores the potential of stormwater harvesting as a supplementary water source and advocates for integrating stormwater management into Darjeeling's urban planning to enhance water security and resilience against seasonal water shortages.

Improving Faecal Sludge Treatment in Nepal: Plant Performance and Management Insights

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Organization: Environment and Public Health Organization (ENPHO) | Nepal

Co-Authors: Bhawana Sharma | Rajendra Shrestha | Jagam Shrestha , ENPHO

Nepal is a stunning country with a diverse geography, ranging from the flat plains of the Terai to the towering hills and the highest peaks in the world, including the majestic Himalayas. There have been several initiatives both from government and nongovernment sectors of Nepal for the Faecal sludge management. Faecal Sludge Treatment plants (FSTPs) in Nepal holds history of more than two decades. To assess the effectiveness of the plants and technologies used for Feacal Sludge Management in Nepal, there was carried out a study by ENPHO under Municipalities Network Advocacy on Sanitation in South Asia Phase II (MuNASS II) program. The study aimed to evaluate the functionality of the treatment plants in Nepal, as there were no documented evidence depicting the functionality of the FSTPs of Nepal. This study is essential for providing recommendation to Nepal government on prioritizing construction of FSTPs and standardizing treatment technologies based upon the country's diverse geographical conditions. The study was carried out in 2024. The study team performed a Key Informant Interview (KII) with the stakeholders from the operators and stakeholders from the respective treatment plants. Observational study was also conducted of the treatment plants listed during the study in verge to understand the functionality and the treatment technologies adopted. The lab test of the effluents was conducted to know about the treatment efficiency of the operational treatment plants. The first FSTP of Nepal was constructed in 1998 at Teku of Kathmandu. Since than approximately 20 treatment plants have been constructed so far and many are in line of construction. Among the treatment plants studied, 12 are functional during the time of the study while 3 treatment plants are dysfunctional and 1 was under renovation whereas 2 FSTPs have already been demolished. While 2 practices deep row trenching. The overall designed capacity of the existing functional FSTPs excluding the trenching facilities is 105 m3 per day. However, only an average of 59.2 m3 of faecal sludge is being treated, indicating the FSTPs are not operating at its full design capacity. This was because of the unwillingness of private desludging service providers to transport to the FSTPs, prevalence of direct application of emptied Faecal sludge to the farmland. Likewise the manual emptying is very prevalent. construction of the containments which percolates liquids directly to the ground is higher which hinders the mechanical desludging service. The treatment technologies used in almost all the FSTPs were based on the biological nature-based treatment process. Most of the treatment plants have a combination of solid-liquid separation units, digestion units and dewatering units to treat the sludge while constructed wetlands were installed to treat supernatant and effluent from consecutive units of treatment process of the sludge. The most common components used were bar screen, Thickening tank, planted/unplanted sludge drying bed, anaerobic baffle reactor and constructed wetland followed by the polishing ponds. The efficiency of the seven operating FSTPs was measured through assessing wastewater discharge quality. pH value of effluents from all the FSTPs were within the permissible limit of the government which is 6 to 9.

During the study period Biological Oxygen Demand (BOD) of all the effluents from the treatment plants except one FSTP was under the national standards for discharging effluents into water bodies which is 50 mg/l. While Chemical

Oxygen Demand (COD) from 3 treatment plants exceeded the permissible limit according to the national standards of Nepal government which is 250 mg/l. Likewise, regarding the Total Suspended Solids (TSS) effluents from only 3 FSTPs complies with the national effluent discharge standard. This depicts that still there is huge attention required from the authorized bodies to set up a good monitoring mechanism to standardize the treatment efficiency of the FSTPs. The study highlights several critical areas where the Nepal government need to intervene to improve the effectiveness of the FSTPs. First, there is a clear need for stronger monitoring mechanisms to ensure that FSTPs operate efficiently and maintain their design capacity. Without robust oversight, many plants remain underutilized or non-functional. The government should establish regular inspection systems and a centralized database to track the operational status of these plants. Additionally, the widespread practice of directly applying untreated faecal sludge to farmland is a major concern. This practice poses significant health and environmental risks, as untreated sludge can contaminate soil and water sources. The government should implement regulations to discourage this practice, raise public awareness, and enforce the safe use of treated sludge for agricultural purposes. Furthermore, the study highlights the problem of unregulated desludging service providers who often bypass FSTPs, opting for unsafe disposal methods. To address this, the government should mandate licensing for all desludging service providers, ensuring that they transport sludge to treatment plants and follow proper disposal protocols.

Lastly, the study points out the inefficiencies caused by over- or under-designed FSTPs. To mitigate this, the government should adopt data-driven planning methods to ensure that treatment plants are appropriately sized based on local needs. Modular or scalable designs could also be considered to accommodate future population growth and changing demands. By implementing these recommendations strengthening monitoring, regulating desludging services, discouraging direct sludge application to farmland, and ensuring efficient resource allocation the government can significantly improve the management of faecal sludge in Nepal and ensure better public health and environmental outcomes.

Trend and Pattern of Access to Sanitation Services in Rural Area Among the Major States in India

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Access to sanitation and hygiene facilities is integral to achieving Sustainable Development Goal (SDG) 6.2, which calls for universal and equitable sanitation and hygiene access by 2030. In India, programs like the Swachh Bharat Mission (SBM) have accelerated progress, but disparities persist across states and socio-economic groups. This study evaluates trends and patterns in sanitation and hygiene access across major Indian states, using NSS data from 2012, 2018, and 2021. It also assesses state performance and convergence through beta convergence analysis and the WASH Performance Index. The research highlights progress, identifies disparities, and provides policy-relevant insights to achieve universal access. The study relies on three rounds of NSS data (69th, 76th, and 78th rounds) to analyze access to sanitation and hygiene services. The data covvers indicators such as access to basic sanitation (improved toilets), handwashing facilities, and hygienic practices. Descriptive statistics were used to track trends and patterns across socio-economic and demographic groups. To measure state performance, a WASH Performance Index was constructed using Multiple Correspondence Analysis (MCA), normalizing scores across survey years. Beta convergence analysis tested whether low-performing states were catching up with high-performing states, with coefficients indicating the pace of improvement.

1. Trends in Sanitation and Hygiene Access - Sanitation access improved significantly from 2012 to 2021. High HDI states saw an increase from 40.1% to 78.5%, while low HDI states improved from 22.0% to 63.8%. Despite these gains, rural areas and disadvantaged groups, including Scheduled Caste/Scheduled Tribe (SC/ST) populations, lagged behind. Similarly, handwashing access surged, with coverage exceeding 77% in both regions by 2021, driven partly by heightened awareness during the COVID-19 pandemic. Socioeconomic factors strongly influenced access. Households with higher education levels, income, and better infrastructure exhibited higher sanitation and hygiene coverage. SC/ST groups and low-income households remained vulnerable, although gaps have narrowed over time. The analysis also revealed gender equality in sanitation access, but female-headed households faced slightly lower access to handwashing facilities.

2. Beta Convergence - The beta convergence analysis indicated that low-performing states are improving faster than high-performing states, suggesting a reduction in disparities. The coefficient for basic sanitation was highly significant and negative (-0.556, $p < 0.01$), indicating rapid progress among low-performing states. Handwashing services also showed convergence (-4.229, $p < 0.10$), though at a slower rate. Despite these encouraging trends, the rate of convergence varied, with states like Bihar, Odisha, and Jharkhand requiring targeted interventions to accelerate progress.

3. WASH Performance Index - The WASH Performance Index provided a comprehensive assessment of state-level sanitation and hygiene performance. High-performing states like Kerala and Himachal Pradesh consistently achieved top scores, reflecting strong infrastructure and policy implementation. In contrast, low-performing states

such as Bihar, Jharkhand, and Odisha, although improving, remained significantly below the national average. Disparities between high and low HDI regions persisted, with the index scores of low HDI states rising from 29.2 in 2012 to 52.1 in 2021, compared to an increase from 46.2 to 77.4 in high HDI states. The findings emphasize the need for tailored strategies to address persistent gaps.

The findings reveal significant progress in sanitation and hygiene access over the last decade, driven by national programs like SBM. However, rural-urban disparities and socio-economic inequalities remain significant challenges. The rapid convergence of low-performing states with high-performing states highlights the effectiveness of targeted interventions, but the slower pace in certain indicators, such as handwashing facilities, underscores the need for sustained efforts. Education and income emerged as key determinants of sanitation and hygiene access. Households with educated members were more likely to use improved facilities, reflecting the role of awareness in driving behavior change. Similarly, income disparities influenced infrastructure availability, with wealthier households better positioned to invest in improved sanitation and hygiene facilities. Caste-based inequities also persisted, with SC/ST households facing lower access despite improvements. The WASH Performance Index highlighted stark inter-state disparities, emphasizing the need for focused policy interventions in low-performing states. While Kerala and Himachal Pradesh demonstrated the benefits of robust public health infrastructure, states like Bihar and Odisha require accelerated investments to meet HDI targets. This study underscores significant progress in sanitation and hygiene access across India but highlights persistent disparities that require policy attention. The beta convergence analysis offers optimism, demonstrating that low-performing states are closing the gap with high-performing states. However, the pace of improvement varies, and low- HDI states still lag significantly in key WASH indicators.The WASH Performance Index provides valuable insights into state-level disparities, enabling policymakers to identify and prioritize interventions in underperforming regions. Achieving universal access by 2030 will require sustained investments in infrastructure, targeted policies for vulnerable groups, and efforts to reduce rural-urban and socio-economic inequalities. Addressing structural barriers, such as caste and income disparities, and promoting education and awareness are critical to ensuring equitable sanitation and hygiene access for all. The findings of this study provide a roadmap for achieving SDG 6.2 and highlight the importance of integrated approaches that combine infrastructural development with behavioral change initiatives. Policymakers must focus on the most marginalized communities to ensure that no one is left behind in the journey toward universal sanitation and hygiene access.

Mapping the Global Research Landscape on Safely Managed Sanitation: A Bibliometric Analysis

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This study provides a bibliometric analysis of the scholarly landscape surrounding Safely Managed Sanitation (SMS) research over the past two decades. By analyzing 550 Scopus-indexed articles published between 2000 and 2023, the study examines the growth, geographical distribution, influential contributors, and thematic focus in SMS literature. The results indicate a significant rise in publications from 2015, largely driven by the Sustainable Development Goals (SDGs). Despite global interest, the research output is dominated by developed countries, with the United States, United Kingdom, and Switzerland leading, while contributions from Sub-Saharan Africa and Asia remain limited.

The intellectual structure reveals key contributors, including Strande L., and highlights influential themes such as faecal sludge treatment, resource recovery, and sanitation technologies. The conceptual structure, analyzed through co-occurrence networks and thematic mapping, identifies dominant themes like urban sanitation and resource recovery, while emerging areas such as behavioral change and faecal sludge characteristics remain underexplored.

This analysis underscores the interdisciplinary nature of SMS research and its reliance on international collaboration. However, gaps persist in addressing region-specific challenges in developing countries and exploring innovative solutions in sanitation planning, treatment technologies, and behavior change strategies. The findings provide a foundation for future research directions, emphasizing the need for greater regional focus and interdisciplinary approaches to address global sanitation challenges effectively. This study offers valuable insights for researchers, policymakers, and practitioners aiming to advance SMS toward achieving the SDGs.

Assessing Public Toilet Facilities in Kerala: Establishing Baseline Data for Improved Service Provision

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The Swachh Bharat Mission (SBM) focus on eliminating open defecation led to mass construction of toilets, including Public Toilets (PTs). However, constructing public toilets does not automatically ensure Rights to Sanitation; poor location, inappropriate design and inadequate maintenance remain constraints for women, elderly and Divyang to use Public Toilet facilities (CPHEEO, 2018).

In 2021, Government of Kerala created the Take-A-Break (T-A-B) Public Toilet Network in a phased manner, constructing high-quality toilet infrastructure in Gram Panchayats, Municipalities and Municipal Corporations. Local Governments were responsible for the T-A-Bs but could engage maintenance agencies or Kudumbashree for service provision. While a significant number of T-A-Bs were created under the Project, not all infrastructure met its purported objectives. Several factors challenge sustainable operations and maintenance (O&M), financial solvency and quality service in Kerala's PTs. Information on toilet infrastructure is available in a tacit form with Local Governments; during campaigns like Clean Toilet Challenge (CTC), aggregate data is collected on multiple parameters. However, collected data is insufficient to support strategies for improved service provision, develop consistent service quality, or propose solutions towards O&M. Given the State's dependence on tourism and high public transport modal share, it is imperative to offer superior PT infrastructure; service delivery; aesthetics; and hygiene. To understand such aspects in Kerala's public toilets, WASH Institute developed an extensive Survey Tool using open-source technology. It will build a robust baseline for toilet infrastructure, enabling local and state governments to take data-driven action for clean, inclusive, safe and sustainable toilets.

Project Objectives

1. Defining a Toilet Rating Index that assesses service quality and functionality in PTs.
2. Identifying specific PT interventions via dashboard and report card mechanisms, at individual toilet level
3. Identifying existing service arrangements, training, and monitoring needs to support superior PT service.

Within a positivist paradigm, the study employed a Mixed Methods Research approach using quantitative and applied research methodologies. A primary survey with close-ended questions is framed on the FACES (Functional, Accessible, Clean, Eco-Friendly, Safe) parameters specified by the CTC 2023. The Survey Tool was developed on the open-source KOBO Toolbox platform. Baseline Assessments, at cubicle-level, were completed in a time-bound manner using the Suchitwa Mission Young Professional (YP) apparatus. YPs were assigned a maximum of ten toilets; every ten toilets thereafter, a surveyor was allotted from among ULB health officials. This reduced individual surveyor load, maximized integrity of the Baseline Assessment and ensured local participation and accountability.

WASH Institute's team conducted district-level hands-on training sessions for ULB and Suchitwa Mission functionaries and revised the Survey Tool to incorporate endemic PT models. Eleven workshops were conducted in all with 74 survey revisions – 250 surveyors across 94 ULBs underwent training. Field analysis was conducted in 25 ULBs to understand PT models within small and medium towns.

1039 toilets with assigned SBM Toilet I.Ds were surveyed under the project, and fifty-six additional functional public toilets identified in the process. Of the universal set of 1095, 280 toilets were found to be dysfunctional, or not functioning as public toilets. Of the remaining, only 53% were functional between the hours of 6 am and 10 pm. The survey process is currently at 93% completion, with 760 of 815 functional public toilets surveyed. Results from the Baseline Assessment are visualized on dashboards generated via Google Looker. Preliminary analyses based on Swachh Survekshan and CTC indicators show that toilets fall short of Accessibility (for women, elderly, disabled and children) parameters. Persons with Disabilities are particularly affected, with less than 50% toilets having ramps or at-grade access for entry. Lighting (affecting Accessibility, Cleanliness and Safety) was found to be inadequate in greater than 50% of toilets, with 30% lacking adequate external streetlighting. Service arrangements were found to be universally weak; while 522 PTs indicated having some type of service contract arrangement, only seventy-six toilet contracts specified service level benchmarks. Despite this laxity, official inspection of PT infrastructure was low, and limited to fortnightly inspections (in 26% of toilets) or a lower frequency. Weak monitoring and enforcement are aggravated by weak grievance redressal systems; 77% of toilets collect user feedback, but less than 50% have a grievance redressal mechanism in place. Similarly, 35% of toilets had no caretaking mechanism, and only twenty-eight caretakers reported undergoing training for PT operations and maintenance. Weak caretaking arrangements and slack service contract renewal have emboldened vandalism in less-inspected public toilets.

The PT Assessment Project has generated in-depth baseline data of urban PT infrastructure, at a cubicle level. It has framed a five-star rating index; instituted dashboard monitoring; and is currently supporting informed decision-making at state– and district– levels. ULBs can use CTC funding to upgrade toilet infrastructure as stipulated in the PT Report Cards. Citizens will soon be able to use Factsheets generated through the Baseline Assessment to understand individual PT service provision and quality, making it a powerful data-driven public advocacy tool. Also significant is the assessment capacity generated among local functionaries involved in the Baseline Assessment; at least 6 ULBs have used the Survey Tool to identify PT infrastructure lapses, immediately rectifying and improving their toilet rating index. This research recommends that new PT infrastructure also undergo the Baseline Assessment, followed by a Monitoring Survey every six months to assess variation in service delivery levels. The open-source KoboToolbox application used for assessments has reduced cost and ensured transparency across multiple levels of government. For example, this study could identify multiple instances of school toilets identified as public toilets, and allotted SBM toilet I.Ds, in order to circumvent PT provision norms; these mis-identified toilets can now be removed from the State's toilet database following the Baseline Assessment. In the event of a public toilet being available, accessibility, cleanliness and safety are key drivers of public toilet use (Moreira et al, 2022). The PT Assessment Project promises to be a data-driven planning tool to ensure these key drivers.

Enhancing Community Engagement in the NAMASTE Enumeration Process in Kerala

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The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act (PEMSRA), penalizes employing manual scavengers, cleaning of sewers and septic tanks without protective equipment, and the construction of insanitary latrines. Conviction rates under this Act have been zero despite stipulating imprisonment and fines for soliciting manual scavenging. The nameless faceless nature of people engaged in such occupations, and their inability to claim justice, created the National Action for Mechanised Sanitation Ecosystem (NAMASTE) Scheme in 2022. It envisions rehabilitation of Manual Scavengers and Workers engaged in hazardous cleaning of Sewer and Septic Tanks (SSWs), promotion of safe mechanised desludging through certified Sewer Entry Professionals (SEPs) and facilitation of SSW access to social security and financial support. Between 2015 and 2017, Kerala saw sanitation mishaps associated with poor supervision, lacking safety measures, and poor communication of safety warnings to onlookers. In 2024, there has been resurgence of septic tank and sewer deaths; to juxtapose, the state was declared manual scavenging-free in 2023.

Kerala's sanitation services are delivered through multiple modes — formal government delivery; service providers contracted via government; and unregistered/unlicensed informal service providers or individuals. SSWs were accessible mainly via word-of-mouth networks, their services advertised in obscure newspapers with an ever-changing slew of contact numbers to evade detection.

The bare-bones structure instituted by NAMASTE established a highly decentralised organogram consisting of 5 State Officers and 94+ ULB Nodal Officers. Online meetings conducted to brief Nodal Officers created negligible outcomes; efforts to collate online spreadsheets of sanitation workers failed – ULBs stated that workers were not locatable, not operating out of ULB jurisdiction, or not disposing of fecal sludge within ULBs. Thus, despite rapidly constituting the NAMASTE State Programme Management Unit (PMU), the Scheme was unable to get off the ground prior to the methodology described below.

Chaskin defines Community Capacity as the interaction of human capital, organizational resources, and social capital existing within a given community (...) leveraged to solve collective problems and improve or maintain the well-being of a given community (Chaskin, 2001). Our methodology employed Action Research from this Community Capacity Building perspective; a sequential workflow was developed with three tasks: Awareness and Consensus Generation (A); Capacity Transformation (C) and Trust Building (T) – ACT for short. The following activities were completed under each of these tasks: 1. Awareness and Consensus Generation - a. The State PMU was consulted regarding implementation challenges, ground-level concerns, related organizations and initiatives, and the present status of manual sanitation work, and b. Kozhikode Municipal Corporation was identified for piloting; meetings with the Health Standing Committee secured an assurance in identifying sanitation workers and CT/PT operators and establishing an ERSU unit prior to the rest of the State. 2. Multi-level Capacity Transformation -

a. In-person orientation workshops focused heavily on the Scheme's humanitarian aspect and highlighted its worker-centric approach. Nodal Officers learned to organize Enumeration Camps, interact respectfully with workers, and strategize for maximum Camp attendance. Enumeration Camps were rolled out across ULBs within PMU-stipulated time-period to improve Scheme efficacy; this reassured SSW apprehensions surrounding punishment and ensured high turn-out, b. By the first Orientation Workshop, Kozhikode Corporation had shown remarkable initiative in instituting Night Squads to identify faecal sludge dumping, impounding three private desludging vehicles, and initiating negotiations with their owners. Kozhikode identified seventy-three sanitation workers without conducting a single Enumeration Camp encouraging competition among other ULBs to identify SSWs, and c. The State PMU supported this momentum via IEC templates for ULBs to advertise their Enumeration Camps, on-call and live support, and assistance from WASH Institute. 1576 SSWs were identified (97% of the estimated number) as part of Enumeration Camps. 3. Trust Building - a. From Scheme roll-out, the State has ensured prompt delivery on Scheme components. Near-100% enumeration has helped 408 beneficiaries avail health insurance via the Ayushman Bharat (AB-PMJAY) Scheme, b. High enumeration rates supported rapid Emergency Response Sanitation Units (ERSUs) formation in all 94 ULBs, followed by immediate Hands-On ERSU Training to four Municipal Corporations. On request, all SSWs enumerated within Kozhikode Municipal Corporation were trained in basic safety and health aspects. Such trainings encouraged other ULBs to request for SEP and SSW training; in response, WASH Institute has been working with Kerala Institute of Local Administration (KILA) to create training apparatus within KILA's campus, and c. Hand-holding support for ERSU safety equipment has allowed ULBs to rapidly size and request for PPE and safety kits. Beginning September 2024, individually sized PPE kits were distributed to SSWs via National Safai Karamcharis Finance & Development Corporation (NSKFDC). 59 ULBs have received PPE kits, potentially benefiting 1267 sanitation workers; distribution of PPE kits is ongoing in all these Municipalities.

Our experience with Kerala's sanitation worker ecosystem supports the following factors for Community Capacity Building: (1) existence of resources, (2) networks of relationships, (3) leadership, and (4) support for mechanisms or processes of participation by community members (Chaskin, 2001). Through continuous engagement, WASH Institute has been: 1. Augmenting existing resources for sanitation worker safety, by creating training infrastructure and modules, developing standard operating procedures for sanitation work, etc, 2. Fostering relations between sanitation workers, their respective NAMASTE Nodal Officers and other organizations to clarify existing avenues for training, complaints or grievance redressal, 3. Creating avenues for organization among sanitation workers by training them in safety procedures and health hazards in sanitation work and making them aware of social welfare schemes and their rights to safe employment, and 4. Supporting collective community action by collaborating with KILA and other similar organizations to deliver trainings across all tiers – from sanitation workers to government officials. The rapid enumeration of Kerala's SSWs was followed by a convening of the State-Level Monitoring Committee to review the implementation of PEMSRA. The Committee reinforced the need for zero-touch processes and upskilling of SSWs to operate machinery effectively; a successful enumeration process is vital to such professionalization within the sanitation workforce.

Water Diaries: Using Oral Histories to Document Women's Experiences of Water Scarcity in Mumbai Suburbs

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Water scarcity is a growing challenge in urban and peri-urban areas, especially in the Global South, where climate change exacerbates existing inequalities in access to essential resources. In Mumbai's suburban regions, women disproportionately bear the burden of inadequate water supply due to their role as primary caregivers and water managers within households. This study adopts a qualitative approach to document and analyze women's lived experiences of water scarcity through oral histories, offering an intimate glimpse into how gender, water, and climate resilience intersect in urban settings. Using semi-structured interviews with women from low-income households in Mumbai's suburbs, the research highlights the physical, emotional, and economic toll of water insecurity. It explores themes such as the daily labor of water collection, the prioritization of family needs over personal well-being, and the psychological stress of living with uncertainty in water access. Furthermore, it delves into how women develop coping mechanisms—ranging from community-based solutions to informal negotiations with municipal services—while simultaneously navigating societal pressures and systemic inequities.

Preliminary findings reveal that water scarcity not only exacerbates household inequalities but also fosters collective resilience among women. Many respondents spoke of forming informal water-sharing networks with neighbors, leveraging these systems to minimize the time and effort spent on water collection. However, these networks often reinforce women's unpaid labor while offering only temporary relief. Additionally, the research found that infrastructural deficiencies, coupled with unreliable municipal services, disproportionately impact women's physical health and mental well-being, further perpetuating cycles of vulnerability and stress. The study examines the implications of these narratives for WASH governance and service delivery in climate-vulnerable urban areas. By centering women's voices, this research underscores the urgent need for gender-sensitive policies and participatory governance models that address water insecurity. It calls for innovative monitoring systems that incorporate qualitative data and oral histories to complement quantitative metrics, ensuring that WASH outcomes reflect the lived realities of marginalized groups.This paper aims to contribute to the broader discourse on inclusive WASH practices by emphasizing the importance of storytelling as a methodological and advocacy tool. It argues that oral histories not only illuminate the socio-cultural dimensions of water scarcity but also offer pathways for designing equitable and climate-resilient interventions. The insights from Mumbai's suburbs, while locally rooted, hold broader implications for addressing urban water challenges across the Global South.

Engaging health facility staff on national standards raises WASH standards

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Adequate water, sanitation, and Hygiene (WASH) services are essential to minimize the risk of healthcare-acquired infections, improve staff morale, patient dignity, and uptake of health services, and can reduce the cost of healthcare. Effective infection prevention and control measures, such as hand washing facilities at the point of care as well as for patients, could reduce healthcare-associated infection by 55% and improve newborn survival rates by 44% . However, the WASH services in many healthcare facilities in low and middle-income countries are below WHO standards. A WHO study of 54 countries from 2015 found that 38% of healthcare facilities do not have an improved water source, 19% do not have improved sanitation, and 35% do not have soap and water for hand washing . This lack of services compromises the prevention and control of infections and, consequently, the ability to provide basic services such as child delivery and sick childcare. This study aimed to assess the impact of engaging health facility staff in raising awareness about Nepal's National WASH Standards in Health Facilities and its subsequent effect on improving WASH services in health facilities in Nepal.

A study include baseline and endline assessments of WASH status in 357 healthcare facilities across 32 districts of five provinces in Nepal covering at least 20% of health facilities in each district. The health facilities were selected based on different criteria like; agro-ecological zone, remoteness, economic (equity quintile), predominant caste/ethnic groups prioritizing the health facilities with the higher risks scores according to above criteria. The study employed a quantitative questionnaire, with data gathered through key informant interviews and observations. Followed by the baseline assessment, including interactive workshop for health facility staff and Health Facility Operation and Management Committees (HFOMCs) presenting deviation on WASH status in their health facilities with respect to the national standard and a tailored action plan was developed by the HFOMC. Regular technical and onsite visit support were provided to the health facilities for the implementation of the action plan developed. An endline assessment measuring the improvements WASH eight months post-intervention.

The study found that the WASH services in health facilities were grossly inadequate and did not meet the National Standard on WASH in health care facilities both at baseline and endline though remarkable improvements were seen at the endline compared to the baseline. But significant improvements were found in key WASH indicators. The percentage of health facilities with functional water storage increased from 69% to 83%, while those with separate drinking water facilities (not common to hand washing and other purposes) rose from 51% to 75%. Similarly, health facilities using any appropriate water treatment method before drinking increased from 79% to 90%. Also, the health facilities with clean toilets increased from 33% to 60%. Hand washing facilities with soap and water in all toilets increased from 38% to 70%, and at the point of care increased from 14% to 40%. However, progress on high-cost infrastructure developments, such as separate toilet facilities for men, women, and individuals with limited mobility, remained limited. The findings demonstrate that even low-cost interventions such as raising awareness about national WASH standards and providing minimal technical support can drive

meaningful improvements in WASH in health facilities. This approach is particularly effective in settings with resource constraints. While improvements were evident, further investment in infrastructure, especially for accessible sanitation, is necessary to meet the comprehensive needs of all patients and staff. These results underline the importance of scaling up WASH awareness of health facilities staff and management committees to improve overall healthcare quality, reduce infections, and enhance patient outcomes, especially in marginalized communities.

The study recommends expanding efforts to raise awareness of national WASH standards across additional health facilities to encourage practical, achievable improvements. For high-cost WASH infrastructure developments, further collaboration and advocacy with local governments are essential to ensure the prioritization of funding. This approach will help reduce facility-based infections, lower mortality rates, and improve both WASH and health outcomes.

Driving Gujarat Towards Net Zero: EV Adaptation as a Strategic Response to Climate Change and Carbon Credit Opportunities

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Gujarat is emerging as a pivotal state in India's pursuit of sustainable development, driven by its robust industrial base and proactive renewable energy initiatives. In the context of rising global warming and climate change, Electric Vehicle (EV) adaptation offers Gujarat a transformative pathway to achieve its net-zero emission goals. This paper explores the multifaceted potential of EV adoption in the state, focusing on its integration with renewable energy, economic opportunities from carbon credits, and its role in climate resilience. The study begins by analyzing Gujarat's policy ecosystem, including its Electric Vehicle Policy 2021, which incentivizes EV manufacturing, adoption, and the development of a state-wide EV charging infrastructure. Leveraging Gujarat's leadership in solar and wind energy, the paper examines how renewable energy integration with EV charging networks can significantly reduce dependence on fossil fuels, thereby curbing greenhouse gas emissions. It also evaluates the potential of coupling EV deployment with carbon credit mechanisms, enabling stakeholders to monetize emissions reductions and attract green investments. Through case studies, the paper highlights ongoing initiatives and projects in Gujarat, such as the deployment of solar-powered EV charging stations and the promotion of electric public transportation in urban centers like Ahmedabad. It discusses the challenges of scaling EV adoption in semi-urban and rural areas, emphasizing the need for inclusive policies that address affordability, accessibility, and infrastructure gaps.

The paper also considers the role of public-private partnerships in fostering innovation and investment, drawing insights from successful global examples adapted to Gujarat's socio-economic context. Governance frameworks, fiscal incentives, and awareness campaigns are examined as critical enablers for creating a culture of sustainable mobility. Ultimately, the study underscores the alignment of Gujarat's EV adaptation strategies with India's commitments under the Paris Agreement and Sustainable Development Goals (SDGs). By positioning itself as a leader in green mobility, Gujarat has the potential to drive economic growth while significantly contributing to global efforts to mitigate climate change. This paper offers actionable recommendations for policymakers, industry stakeholders, and urban planners to accelerate Gujarat's transition to a net-zero future.

Rejuvenation of Traditional Stone Spouts ('Hitis') for Climate-Resilient Urban Water Management

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In the Kathmandu Valley, 'Hitis'—ancient Stone Spouts—stand as a testament to historical governance practices in sustainable water management where traditional systems existing side by side with modern infrastructure. 'Hiti Pranali' is a decentralized yet integrated water management system, unique to Kathmandu Valley rooted to the Lichhavi era (approximately 1700 years ago). These stone spouts extract water from underground aquifers through an intake system called 'Navimandal'. It is a manifestation of climate-resilient and inclusive urban water governance. Despite the convenience provided by the pipeline, locals still prefer water from these spouts, as they are concerned with the quality and reliability of tap water. However, urbanization, encroachment and water scarcity have threatened these historic structures, risking their disappearance. A determined movement to revive traditional water management practices highlights governance that fosters climate resilience water management practices. In response to this pressing need, the Integrated Urban Water Management (IUWM) Project, led by ENPHO in collaboration with BORDA South Asia and Godawari Municipality, embarked on a journey to restore 'Simako Dhara', a stone spout located in Patalechhap, Bishankhunarayan. This stone spout, serving over 250 households, underwent a significant transformation in 2021. The restoration project tackled water scarcity while preserving cultural heritage, promoting sustainability, and empowering communities. By enhancing safety, convenience, and aesthetics, it not only improved the water-fetching process but also served as a community-driven governance model for reviving these structures, thereby enhancing resilience to climate change.This project not only addressed immediate water management needs but also established a foundation for scaling similar initiatives across the region. The major objective was to preserve the traditional significance of stone spouts while fostering communities to take charge of water management and governance, ensuring a sustainable and climate-resilient supply of safe water for everyone. The restoration process, guided by collaborative governance, involved municipality, local ward, Water User Committee (WUC), and ENPHO working together to rehabilitate traditional stone spouts. Site visits and stakeholder consultations identified Simako Dhara and 13 other spouts for renovation under the IUWM project. ENPHO provided technical assistance through Detailed Project Reports (DPRs), which served as blueprints for sustainable and inclusive restoration adapting to climate challenges.

Infrastructure enhancements, paired with active community involvement, played pivotal roles in the transformation of the stone spouts into thriving community assets. Enhancements like garden area, seating arrangements, elevated platforms, and upgraded pathways were added to boost functionality and enhance the aesthetic charm of the stone spout site. Upon completion, the renovated stone spouts were handed over to the respective municipality and the community for operation and maintenance (O&M). The roles of Water User Committees (WUCs) were instrumental in overseeing the restoration process, ensuring sustainability, and facilitating ongoing maintenance efforts. Community-led enhancements and transformations such as captivating lighting for night views added to the spouts' visual and functional appeal. Basic parameters of water quality were rigorously tested to ensure the

safety of the water, addressing a critical community concern. By empowering communities and incorporating technical expertise, the project not only preserved cultural heritage but also demonstrated a scalable model of climate resilient urban water management practices. The success of Simako Dhara's restoration showcased the effectiveness of community-driven governance and resonated with a wave of requests for similar renovations leading to the rejuvenation of additional stone spouts in Godawari and Kirtipur Municipality. In 2022 and 2023, the proactive response from municipalities, coupled with technical support from ENPHO, demonstrated strong governance by spearheading restoration of Majha ko Dhara, Bhujure ko Dhara, and Bishankhu Narayan. Similarly, Kirtipur Municipality undertook the renovation of Nakhi Gaa Hiti and Chi Gaa Hiti. These efforts underscored the replicability and scalability of the project, creating a ripple effect of community-led conservation initiatives.

The project successfully upheld the cultural heritage embodied in the stone spout while simultaneously guaranteeing access to clean and safe water for the local community. The renovation efforts have benefitted 11,650 individuals across these stone spouts. Beyond enhancing safety and convenience, the restoration offered esthetic enhancements to the water fetching process. Community involvement was a key driver of success, with residents actively participating in the restoration process and contributing to the project's long-term sustainability. This project not only restored indigenous water systems but also sought to set a model for the revival of these climate resilient water management system in the region. The restoration of traditional stone spouts exemplifies the transformative role of governance, community collaboration, and innovation in addressing urban water management challenges. By revitalizing indigenous water systems and improving water access in urban areas, this project directly addresses the challenges outlined in SDG 6 which aims to ensure access to clean water and sanitation for all. The initiative supports SDG 11 by preserving stone spouts as cultural landmarks and transforming them into inclusive community spaces, fostering sustainable urban development. Its alignment with SDG 13 highlights the role of traditional water systems in combating climate change, showcasing how ancient practices address modern environmental challenges. By promoting the use of traditional water systems and reducing reliance on energy-intensive infrastructure, this project supports climate resilience and mitigation efforts, contributing to the overall sustainability agenda.

Beginning with the successful rejuvenation of Simako Dhara, this project sparked a ripple effect, inspiring neighboring communities to replicate the initiative. The restoration of traditional stone spouts embodies a holistic approach to water management, blending climate-resilience, heritage conservation, community empowerment, and technological innovation. This project serves as a compelling example of how governance, community leadership, and innovation can converge to address water scarcity, promote sustainable development, and build climate resilience, offering a replicable model for urban WASH solutions.

"Governance, Behavior, and Public-Private Partnerships in Sustainable Solid Waste Management: Insights from Darjeeling

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Hill towns like Darjeeling face intricate solid waste management (SWM) challenges due to constrained geography, limited land for waste processing, and a high influx of tourists, who contribute in doubling of waste during peak seasons. This study examines Darjeeling's SWM landscape through a vertical dissection of the service chain—segregation, collection, transportation, treatment, and disposal—and a horizontal analysis of governance, behavioural dynamics, and financial sustainability. Primary surveys and GIS-based mapping reveals a system striving to balance operational demands with available resources, while adapting to very specific environmental pressures. Darjeeling has achieved 100% door-to-door collection in 27 of its 32 wards (as per primary surveys) and reports source segregation at the household level. Yet, there are challenges, including the mixing of segregated waste during transportation and limited secondary segregation capacity. Approximately 10 tons of segregated plastic waste is sold weekly to scrap dealers in Siliguri, underscoring the critical role of informal waste recovery networks. The city's reliance on a single dumping chute to handle 35 tons of solid waste daily. This has led to environmental concerns such as leachate contamination, microplastics entering the Teesta River system, and methane emissions from garbage fires, worsening localized climate impacts. The city's waste system, already under strain, is further burdened by erratic weather patterns linked to climate change, which disrupt waste management logistics and increase ecological risks in the fragile Himalayan ecosystem.

Governance efforts by the municipality and private operators demonstrates a strong commitment, yet the absence of a cohesive framework integrating stakeholders, particularly informal networks, limits the system's efficiency. Behavioural dynamics further hinders the system, with some wards showing full support for single-use plastic ban while others exhibit resistance. Financially, the SWM system faces challenges in cost recovery and lacks investment in scalable technologies such as decentralized treatment units and resource recovery from waste systems.Tourist influx exacerbates these challenges, creating seasonal surges in waste generation that strain infrastructure. This study seeks to explore how Darjeeling's SWM can be strengthened through integrated governance, inclusive stakeholder participation, and innovative financial mechanisms. By illuminating the city's efforts and challenges within a broader framework, it aims to highlight pathways for sustainable waste management, balancing environmental protection, social inclusion, and economic feasibility in resource-constrained hill towns.

Parametric Assessment of Water-Energy-Food Nexus of India

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This research focuses on parametric and spatial analysis of the Water-energy-food nexus of India and its states. India is an emerging country, products produced in India utilize the resources at the utmost level and supply across the globe, which requires water, energy, and food to feed the labor involved. At present India is one of the water-stressed countries. It is an alarming situation as our life is based on a water-centric cycle. For example, the electricity we use needs water for generation and crop cultivation. India being one of the growing countries lacks the study in water-energy-food nexus. Only 7% is contributed by India to the study of the Water-Energy-Food Nexus. And within that percentage of study, no spatial research is done. The present study carries a literature review by Bibliometric analysis and thematic analysis. Also, this study implies why parametric analysis and spatial analysis are needed to study the Water-Energy-Food nexus on the parameter of availability and accessibility of resources for understanding the interlinking relationships of the resources. Way forward studies in the sector of Water-Energy-Food nexus will not only help in managing and sustaining the natural resources but will also be a great framework to plan the growing cities of India to be climate change resilient.

People's Perception on Climate Change in Gorkha District

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Local peoples' knowledge and perception is one of the important strategies to find out the scenario of climatic events and impacts. As Nepal is one of the climate change impacted countries in the world, it is essential to carry out place or community based studies to gather information on climate change in Nepal. Gorkha is one of the greatly impacted district by climate change but the studies on people's perception of climate change is scarce. A study was carried out in two villages of Gorkha Municipality, Gorkha by implementing a set of questionnaire to know the perception of local people on changing trend of climate. The local people have perceived increasing trend of temperature, extension of summer and reduction in the length of winter season. Late starting of monsoon, untimely rainfall, and reduction in the amount of rainfall was also reported. These changes have impacted crop cycle, productivity, crop diseases and postharvest loss. The amount of water has been reduced severely in the natural sources like well, spring and rivers. Similarly, the hail stone pattern, formation of dew, formation of fog and the strength of storms shows the changes in comparison to past 20 years. The local people have been trying to adapt with these changes by crop diversification, using chemical measured to control crop diseases and changing their livelihood strategies. Since the district is also seriously affected by 2015 earthquake it is recommended to focus the district for suitable adaptation measure.

Advancing towards Inclusive and Climate-Resilient WaSH for Vulnerable Urban Communities in India: The Case of Ahmedabad and Surat

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Rapid urbanisation, while bringing lucrative economic opportunities to cities, has also spurred the emergence of informal settlements due to migration. These informal settlements often suffer from poor living conditions and a lack of infrastructure, crucial for resilient and sustainable communities. According to the recent WHO 2019 estimates on Water, Sanitation, and Hygiene (WaSH) related burden of disease estimates, 1.4 million people die each year because of inadequate drinking water, sanitation, and hygiene. Access to sanitation is recognised as a basic human right by the United Nations. Further, Sustainable Development Goals (SDGs) 3, 6, 11, and 13 emphasize the importance of good health and well-being, sustainable water and sanitation management, and climate action, highlighting the need for safe and inclusive sanitation for all. Therefore, an inclusive approach to safe sanitation is essential to mitigate sanitation disparities. This empirical research aims to critically analyse sanitation conditions and infrastructural challenges of the two metropolitan cities of Gujarat (India) - Ahmedabad and Surat. Through their various plans and programs, the cities aim to ensure that no community is marginalized and that all residents have resilient and equitable access to basic infrastructure facilities. However, according to various reports and primary data collection, there still is a lack of last-mile connectivity and inclusive sanitation. Moreover, sanitation issues are further aggravated by increased climate-induced risks associated with frequent occurrences of events such as urban flooding. The study focuses on assessing such service availability, access, quality, and affordability-related gaps and opportunities in the sanitation conditions of the two cities. The study adopts mixed methods to collect and analyse evidence through 6 focus group discussions, 30 household surveys, and 7 key informant interviews were conducted to collect diverse qualitative data from stakeholders. Further, mapping and policy reviews were done to analyse the primary and secondary data. Finally, borrowing from the global and national practices and the available frameworks to evaluate the infrastructure service provisioning in slums, the research develops a toolkit to assess the vulnerable slums in Ahmedabad and Surat. Based on the stakeholder consultations and results from the toolkit, Prem Nagar Darga slum in Surat and Shankarbhuvan slum in Ahmedabad were identified for further piloting. An analytical framework was developed to further study the sites, emphasizing the importance of climate-resilient, gender-sensitive, and inclusive infrastructure within slum settlements. In Ahmedabad, the research highlights significant disparities influenced by socio-economic factors, cultural norms, and infrastructural deficits, with particular emphasis on the adverse effects on women due to gender biases and restricted access to sanitation facilities. Similarly, in Surat, the research highlights disparities in areas such as inadequate housing, insufficient infrastructure (including sanitation and access to quality water), and the geographical location of residence or workplace. Contrary to this, several other slums in the cities like R.R. Shukla ni Chali in Ahmedabad (community awareness), Mochivas ni Chali in Ahmedabad (through support from Mahila Housing Trust, and Sanskar Colony slum in Surat (through government initiative under Slum Upgradation cell) have made significant improvement in terms of infrastructure and liveability. Community engagement,

especially through SHGs, has demonstrated notable benefits in some slums by empowering women to actively participate and articulate their needs in sanitation projects.

Climate risk poses significant challenges to urban water supply and sanitation systems, affecting their availability, quality, and reliability. Many slums are located on flood-prone land, where residents are forced to practice open defecation due to outdoor toilets and sewer backflows, moreover, increasing extreme weather events, such as heavy rains and storms, exacerbate urban flooding, overwhelming drainage systems and contaminating freshwater sources with untreated sewage. Tragically, approximately 4.3 percent of Ahmedabad's land is susceptible to flooding and waterlogging, disproportionately affecting 9 percent of its residents, particularly those in slum districts. These disruptions not only strain water resources but also heighten the risk of waterborne diseases such as cholera and dysentery, particularly in vulnerable communities. Addressing these challenges requires resilient urban planning, robust infrastructure, and adaptive strategies to ensure sustainable water supply and sanitation systems in the face of a changing climate. Lastly, the study highlights the role of community engagement and resource convergence in addressing the unique vulnerabilities of these communities. It calls on academics, policymakers, and urban planners to integrate adaptive, resilient strategies into urban planning to enhance the capacity of informal settlements to cope with and adapt to climate impacts.

Caste, Climate, and Sanitation: Analysing Film and WASH through an Intersectional Lens

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Analysing the role of caste in labour studies and economics has often been overlooked in India and across South Asia. While much of global governance and intervention focuses on the outcomes of WASH through sustainability and developing newer technology to advance several pertinent issues, such as water scarcity and accessibility, the framework of caste as tangential to studying the sector remains unexplored to an extent in scholarship. On one hand, disciplines of sociology, anthropology, and cultural studies do examine the permeability of caste into different fields of work and livelihood, but a deeper connection must be made between the two. Any discourse on developing the WASH sector, especially through local and global governance cannot invisibilise how only 'lower' caste groups in India constitute the largest cleaning workforce in both urban and rural spaces. This paper seeks to highlight the need to closely examine intersections of caste, class, race, and gender in an overarching theoretical framework that borrows from the school of subaltern studies. In India, 'scientific' and empirical research often shies away from addressing questions of caste, claiming it to be an issue of a past and bygone India. Sadly, the reality of millions of sanitation workers, cleaners, and labourers continues to shape the lives of citizens, whose trajectory in life continues to be circumscribed by their caste identity.

The future of WASH studies must advocate for greater inclusivity through a critical investigation of caste and its impacts on the primary caretakers of sanitation across South Asia. In this paper, I aim to connect the role of representation in film and literature in order to create a space that allows for a nuanced discussion on contemporary issues of caste and manual scavenging. Even though manual scavenging is banned, it continues to be a form of waste management in a widespread manner. Two films, Manhole (2016) and Kakkoos (2017) delve into the issues and impacts of manual scavenging as detrimental to human rights and the dignity of workers. This paper shall outline the current challenges that WASH studies face without the inclusion of intersectionality through a close analysis of these films to outline questions on accessibility, representation, and human rights.

I also examines how entrenched caste hierarchies exacerbate inequalities in access to WASH infrastructure, perpetuating socio-economic marginalization and health disparities. Historically marginalized communities, such as Dalits, are disproportionately burdened with unsafe sanitation practices and limited access to clean water due to systemic exclusion and discriminatory practices. These vulnerabilities are further amplified by climate change, which intensifies water scarcity, extreme weather events, and sanitation-related challenges.

By analyzing policy frameworks and grassroots movements, this research highlights the structural barriers to equitable WASH services and their implications for environmental justice. It critiques the gaps in government programs like Swachh Bharat Abhiyan, focusing on the socio-cultural dimensions of sanitation and their entanglement with caste hierarchies. Furthermore, it explores how climate-induced crises disproportionately impact vulnerable groups, reinforcing cycles of poverty and social exclusion. The study argues for a holistic and

intersectional approach to WASH policies that addresses caste-based inequities and integrates climate resilience strategies. Such an approach is essential to achieve sustainable development goals, ensure public health equity, and combat the socio-environmental challenges of a changing climate in India.

Moreover, I also link the role of literature and film to act as a site of change and to advocate for caste sensitive WASH policies. I analyse how embedded forms of caste hegemony in India continue to thwart laws from becoming a reality and become obstacles in governance. This is an issue that must be taken into account to ensure safety, justice and equity take centre stage in conversations on climate change and WASH. Can literature, film and scientific collaboration reshape our understanding of caste and climate issues? How do we represent questions on accessibility and dignity with sensitivity? What role can the visual medium play to exemplify voices that have been marginalised historically and are rendered nameless in official records and reports? These are some of the questions my paper hopes to raise.

Coordination Among Government Tiers for Safely Managed Sanitation in Nepal : How local government can sustainably operate a large scale wastewater treatment plant built by Federal Government

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Coordination and partnership among the three tiers of government in Nepal—federal, provincial, and local—are vital for effective governance and the implementation of federalism as envisioned by the Constitution of Nepal, 2015. The federal government oversees national policies, provincial governments manage regional priorities, and local governments address grassroots needs, creating an interconnected framework. Effective coordination ensures the seamless distribution of resources, avoids duplication of efforts, and promotes uniformity in service delivery. However, challenges such as overlapping jurisdictions, political differences, and resource constraints often hinder collaboration (Bhatta, 2019).

The paper is based on the literature review and key informants panel discussion at the national level workshop dialouge and stakholders consultation. Six key questions were formulated to ask the local leaders and key officials engaged with the three tiers of government in Nepal, namely: Ministry of Water Supply, Bagmati Provincial Government - Province Assembly Member and Local Government (Kathmandu Metropolitan City Office).

Focusing on the sustainable operation of large scale wastewater treatment plant in Nepal, such as Guheshwori WWTP, there are challenges such as seasonal variations in wastewater inflow, inconsistent inflow quality and inadequate sludge management. The Water Supply and Sanitation Act formulated in 2022 has mentioned the wastewater management and treatment as the responsibilites and obligations of Provincial Government, although the Federal Government will allocate necessary budget, and it will be managed for sustainable operaiton by Local Government.

The local government in Nepal (municipalities, rural municipalities and metropolitan cities) alone cannot manage WWTPs and need provincial support and inter-ministerial cooperation. The strength of local governments is that they have autonomy in managing the water water and solid waste management at operational level. However the supports are required in technical skills, operational resource mangaement (such as tariff system development), sludge mangement.

Statistics show significant progress in sanitation coverage, but this does not always guarantee safely managed systems. Meanwhile the inequities faced by marginalized communities, particularly Dalits, Musahars, and Chamars, due to poverty and systemic exclusion should timely guide towards inclusive sanitation policies and a rights-based approach to ensure no one is left behind. Addressing these requires fostering mutual respect, clarifying roles, and enhancing capacity-building programs across all levels (Sharma, 2021). Partnerships should also leverage technological advancements for efficient communication and monitoring (Ghimire, 2020). Strong inter-governmental coordination ensures equitable development, strengthens democratic practices, and promotes public trust in governance.

Understanding the Accessibility Challenges in Urban sanitation for People with Disabilities in India

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Access to clean and adequate sanitation remains a critical challenges in India's urban landscapes, despite being recognised as a fundamental necessity since independence. The condition of the urban sanitation facilities significantly impacts public health and quality of urban liveability. According to Census 2001, about 7.87 percent of urban households lacks access to latrines, and defecate in open, while about 8.13 percent of urban households use community facilities, and 13.4 percent utilizes shared facilities. Out of the total about 26.83 percent of households are connected to open drains and 13 percent of the total urban households do not have any drainage network. This challenges exacerbated among the urban poor, vulnerable populations including women, marginalised population, children and specifically people with disabilities are disproportionately affected.

Urban sanitation facilities often fail to accommodate the diverse needs of the people with disabilities, such as wheelchair uses, individuals with visual impairment and those with cognitive disabilities. Persistent issues, such as poorly maintained facilities, inaccessible locations, and absence of assistive features exacerbate the exclusion experienced by the people with disabilities. Furthermore, social stigma and lack of sensitization in institutions and communities further alienate the people with disability communities from the public sanitation systems.

A review of existing policies, including the rights of persons with disabilities Act, 2016, and guidelines under Swachh Bharat mission reveals the significant gaps in their implementation and monitoring. The lack in awareness and training in universal design principles for the stakeholders involved in the design, planning and implementations of the sanitation infrastructure further widens the gaps further. Additionally, lack of robust data on the specific needs and challenges faced by the people with disabilities in accessing sanitation infrastructure demands urgent attention.

This paper addresses these challenges and advocates for a multi-pronged approach: strengthening policy implementation with clear accountability, adopting universal design principles, increasing community awareness and leveraging technology for accessible sanitation solutions. Understanding addressing the data gaps and the unique challenges, faced by the people with disability in urban sanitation is vital for achieving equitable accessible urban development and fulfilling India's commitment to SDG 6 on clean water and sanitation. The proposed study underscores the urgency of integrating accessibility into urban sanitation planning to ensure safety, inclusivity and accessibility for all.

Deciphering Policy processes of climate resilient Faecal sludge management in Odisha

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India has seen dramatic transformation in terms of the sanitation infrastructure through the introduction of Swachh Bharat Mission (SBM) in 2014 which aimed to eliminate open defecation. SBM significantly increased access to toilets addressing the front end problem of access in sanitation with construction of over 6 million urban toilets however the majority of the urban allocation of budget has been used to build toilets leaving little money for safe faecal sludge disposal. Towards handling the increasing amount of excreta generated across India, two key technological approaches have been used. First, the centralised sewer based systems where excreta is transported in underground sewer networks to a sewage treatment plant. It has been historically prevalent in metropolitan cities. Second being the decentralized non-networked sanitation systems (NSS) such as FSM which is focused on treatment of excreta at a different site.

Given the challenges faced by small towns, the government of Odisha has made an attempt to provide sanitation services to its citizens across all its 115 cities and towns. This scale up has engaged various state and non-state actors in various multi-stakeholder policy processes to tackle the back-end sanitation challenges of the state. This paper attempts to understand the policy processes in scaling up of FSM in Odisha.

Designing a Competency Framework for Water Governance

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Water resource management is a complex process that spans the entire lifecycle—from resource availability and usability to treatment, reuse, and eventual disposal. Ensuring safe and adequate water supply requires not only technical expertise and sustainable practices but also robust governance structures to address challenges such as rising global water demand, diminishing freshwater availability, and the growing intricacy of decentralized systems. Despite significant efforts to improve service delivery, gaps persist in aligning institutional capacity with the scale and complexity of water-related interventions. Public-sector systems often encounter fragmented roles, unclear responsibilities, and weak limited accountability mechanisms, leaving critical gaps in service delivery and undermining the effectiveness of water-related interventions. These challenges become particularly acute at the last mile of service delivery, where skill gaps become more pronounced as one moves down the organizational hierarchy. The absence of competency-based job descriptions and structured, role-responsive hiring processes results in misaligned recruitment and inadequate preparation for on-ground delivery. This misalignment limits the ability of officials to meet role-specific demands effectively, further compounding inefficiencies in the system. A comprehensive, competency-based framework is essential to align recruitment, training, and performance evaluation processes with the multifaceted demands of water governance. Competency, defined as a combination of attitudes, skills, and knowledge (ASK), equips individuals to perform their roles successfully. While competency mapping has traditionally been focused on senior leadership to clarify strategic roles and responsibilities, its true potential lies in extending across the entire organizational hierarchy. When applied comprehensively, competency mapping functions as a theory of change - starting with broad institutional goals and breaking them into actionable specifics - ensuring that every stakeholder, from strategists to on-ground implementers, meaningfully contributes to an integrated, accountable, and sustainable water management system.

This research seeks to develop a comprehensive Competency Framework to identify, define, and map competencies across all stages of the public water resource management lifecycle. By doing so, it seeks to equip decision-makers with a clear understanding of “what” competencies are needed to ensure sustained efficiency, adaptability, and accountability throughout the system. Drawing inspiration from the Framework of Roles, Activities, and Competencies (FRAC), the proposed approach takes a bottom-up perspective, addressing gaps at every level while aligning organizational roles, responsibilities, and resource needs. This novel approach emphasizes targeted role definitions, anticipated gap identification, and precise diagnostics for capacity-building efforts, fostering adaptability while maintaining alignment with broader organizational goals. The methodology involved a needs assessment and analysis of public domain datasets to address gaps in bottom-up competency mapping within the water ecosystem. Field observations, one-on-one interactions, and focus group discussions (FGDs) were conducted with approximately 200 stakeholders, including beneficiaries, across different hierarchies. These included five key stakeholder groups responsible for sustaining rural water systems across seven districts of

Assam. These engagements provided a broader understanding of the ecosystem's requirements and informed the framing of the problem statement. Secondary research included a review of existing frameworks, such as FRAC, Competency Framework Guide for Drinking Water Quality Technicians, CIWEM (Chartered Institution of Water and Environmental Management) Competency Framework Support Document 2019, and others allowing the adaptation of relevant principles to the dynamic needs of the water sector.

The framework development process builds on these insights by systematically mapping workflows, and required competencies from the bottom-most tiers upward, ensuring an inclusive and diagnostic approach. It identifies gaps in the efficient functioning of the system, particularly through the Human Resources lens, and emphasizes setting clear expectations at the entry point of each defined level. By addressing these gaps, the framework not only highlights areas for capacity-building interventions but also ensures alignment with broader organizational goals, fostering better resource allocation and enhanced system efficiency. This bottom-up approach brings a novel perspective by creating a cohesive structure across the hierarchy. This framework is intended to be dynamic and adaptive, recognizing that it is merely the starting point in a continually evolving water management landscape. As technological advancements, infrastructure designs, and policy mandates reshape the ecosystem, the defined competencies and approaches will require periodic updates, course corrections, and innovation in capacity-building strategies and tools. This flexibility ensures that the framework remains relevant and effective in addressing emerging challenges, supporting long-term sustainability, and fostering continuous learning and improvement across all levels of the water management system.

The Need for Climate-Responsive PPEs for Sanitation Workers: Insights from Odisha's Successful Garima Intervention

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Sanitation workers, integral to public health systems, endure some of the harshest working conditions, which have been exacerbated by the impacts of climate change. Rising temperatures, erratic rainfall, and frequent cyclonic activities significantly heighten their occupational hazards. While personal protective equipment (PPE) is a critical safeguard for sanitation workers, it often fails to meet the unique demands posed by such environmental challenges. A fundamental step toward ensuring that sanitation workers receive appropriate PPE is their enumeration and identifying their job roles so as to assign appropriate PPEs. Identifying and documenting sanitation workers is crucial for understanding their needs, advocating for their rights, and delivering tailored safety interventions. Through our on-ground efforts and partnerships with national and state government, over 1.5 lakh sanitation workers have been enumerated under scheme like Garima, Sanitation Workers Development Scheme(SWDS), and NAMASTE. Odisha's "Garima" Scheme, is a pioneering initiative aimed at enhancing the dignity, safety, and welfare of sanitation workers, serves as a model framework for tackling these issues of providing appropriate PPEs. The state's comprehensive approach to PPE provision under Garima demonstrates the potential for integrating climate responsiveness into sanitation safety programs. By undertaking systematic assessments, engaging stakeholders such as workers and manufacturers, and institutionalizing quality standards, Odisha has laid a foundation for addressing climate-induced vulnerabilities. This paper delves into Odisha's Garima intervention, highlighting its processes, achievements, and the gaps that still exist in creating climate-resilient PPEs tailored to the needs of sanitation workers.

Sanitation workers in Odisha encounter a unique interplay of occupational and climate-related risks that make their work increasingly perilous. The state's intensifying heatwaves, coupled with a tropical climate marked by high temperatures, elevated humidity, and moderate to heavy rainfall, put workers at heightened risk of heat exhaustion and dehydration. Odisha's summers are particularly harsh, with temperatures often exceeding 40°C in interior and western regions. The data suggest, maximum temperatures have shown an upward trend over time. Coastal areas like Bhubaneswar, with humidity levels reaching approximately 75%, create extremely challenging working conditions for sanitation workers. The southwest monsoon, which typically begins in mid-June, brings significant rainfall through September.

During monsoons, heavy waterlogging increases workers' exposure to contaminated waste and waterborne diseases, while cyclones exacerbate risks during post-disaster cleanup operations. These climatic challenges are compounded by everyday occupational hazards, including exposure to sharp objects, toxic chemicals, and biological waste. Despite the availability of personal protective equipment (PPE), much of it is ill-suited to the compounded risks posed by Odisha's climate. This inadequacy is particularly pronounced for female sanitation workers, who often receive PPE that is poorly designed to fit their ergonomic needs. Ill-fitting gear not only compromises their safety but also reduces their efficiency at work. Odisha's Garima Scheme provides valuable

insights into addressing these challenges. By focusing on the unique vulnerabilities of sanitation workers and prioritizing climate-responsive PPE, the initiative highlights critical steps toward ensuring their safety and well-being.

The PPE Process Under Garima: A Holistic Approach: The Garima Scheme's approach to PPE provision is rooted in a structured and participatory process, ensuring that the solutions developed are both practical and sustainable. At the core of this effort is the recognition that sanitation workers themselves must be central to any initiative designed to protect them. The first step in this process was conducting a PPE assessment study. This study involved engaging with sanitation workers across various categories of work—Sewer & septic tank cleaning, drain cleaning, CT/PT cleaning, Operation & Maintenance of FSTP—to document their lived experiences with existing PPE. Workers were asked to share feedback on issues such as comfort, durability, effectiveness, and suitability for different environmental conditions. Their insights revealed widespread dissatisfaction with the safety gear provided, particularly its inability to withstand heat, waterlogging, and prolonged physical exertion.

Based on these findings, the state organized a roundtable discussion involving manufacturers, suppliers and health& safety experts. This platform provided an opportunity for raise the concerns directly to manufacturers and for experts to outline the need for innovations that align with climate resilience. The dialogue led to a mutual understanding of the gaps in existing PPE and the scope for developing better solutions, such as heat-resistant materials, waterproof fabrics, and ergonomic designs.

To ensure quality and consistency, Odisha moved towards a state-level empanelment of PPE suppliers. This process was guided by the findings of the assessment study and feedback from the roundtable discussions. Suppliers were selected based on their ability to meet defined quality standards, including climate-adaptive features, durability, and affordability. By institutionalizing this empanelment process, Odisha created a mechanism to ensure that sanitation workers consistently receive PPE that meets their needs and adheres to state-mandated standards. Furthermore, the Garima Scheme incorporated a robust system for Sanitation worker's training and feedback. Sanitation workers were provided with practical training sessions on the proper use (donning & doffing), maintenance, and disposal of PPE. Regular feedback loops were established to monitor the performance of the supplied gear, with insights feeding back into procurement and policy decisions. Despite the progress achieved under Garima, the intensifying impacts of climate change necessitate further enhancements to PPE. Climate-responsive PPE must be designed to mitigate specific risks such as heat stress, prolonged water exposure, and cyclone-induced hazards. Key features should include lightweight, breathable materials with integrated cooling technologies, durable waterproof fabrics, and ergonomic designs tailored to the needs of both male and female workers.

The insights gathered from Odisha's systematic process—worker-centric assessments, stakeholder engagement, and institutionalized quality control—offer a replicable model for other states and regions. By leveraging these lessons, Odisha is well-positioned to pilot the next generation of climate-adaptive PPE and scale its use across the sanitation workforce.

The Garima Scheme stands as a testament to Odisha's commitment to improving the safety and dignity of its sanitation workers. The participatory and structured approach adopted under the scheme—starting with grassroots assessments and culminating in state-level institutional reforms—offers a powerful framework for addressing the challenges posed by climate change.

As the state moves forward, integrating climate resilience into its PPE standards is not just a necessity but also an opportunity to lead the nation in safeguarding one of its most vulnerable workforces. Odisha's success can inspire a nationwide shift towards climate-responsive safety measures, ensuring that sanitation workers everywhere are equipped to withstand the growing challenges of a changing world.

Study on perception of sewer systems vs septic tank systems in Maradu Municipality of Kerala

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The research aims to address critical challenges in the WASH (Water, Sanitation, and Hygiene) sector, particularly in the context of urban governance and climate change resilience. This study focuses on evaluating the recovery and rehabilitation efforts in the Maradu municipality following substantial disruptions caused by unplanned urbanization and ecological degradation. The overarching objective is to propose evidence-based strategies for sustainable WASH solutions that align with broader goals of environmental and public health. The research, conducted in Maradu Municipality of state of Kerala in India aimed to evaluate perceptions of sewer systems versus septic tank systems, assess current used water management practices, and estimate willingness to pay for a sewer network. The methodology employed a structured, mixed-methods approach to ensure robust data collection and analysis. The findings highlight the need for improved infrastructure, community engagement, and awareness campaigns to transition toward sustainable used water management. While septic tanks remain widely accepted, their limitations underscore the potential benefits of sewer systems if implemented effectively. Key recommendations include piloting sewer systems in receptive wards, building community trust through transparent governance, and integrating successful models from other regions to address the unique challenges of Maradu Municipality.

Used water Management Strategies for Kerala: Case study of 10 towns from Kerala

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Kerala is the southern state with unique geography, high population density, and diverse socio-economic conditions. The state faces significant challenges in managing its wastewater effectively. The consequences of mismanaged wastewater are evident in the rising incidents of waterborne diseases, groundwater contamination, and environmental degradation. Recognizing the urgency to address these issues, the Used Water Management (UWM) Strategy was formulated to provide a comprehensive, replicable framework for sustainable wastewater management across the state.

Problem Statement - The mismanagement of wastewater in Kerala presents multifaceted challenges - Water Pollution: Discharge of untreated sewage and greywater directly into natural water bodies has increased pollution, impacting ecosystems and public health, Health Risks: Poor sanitation practices elevate health risks, with faecal contamination detected in numerous water sources, Infrastructure Gaps: The lack of standard templates and model documents for UWM hampers efficient project planning and implementation, and Operational Inefficiencies: Absence of localized, need-based project formulation delays UWM initiatives, wasting resources and impeding the establishment of a resilient sanitation infrastructure.

The initiative to prepare a UWM strategy for Kerala is based on this established methodology used for Used Water Management study conducted by WASH Institute. However, recognizing the state's distinct geographical, environmental, and socio-economic characteristics, the methodology has been further refined into a state-specific replicable framework. This was executed after analyzing the findings from the pilot studies conducted in 10 towns across Kerala. The present study on developing the used water management strategy for Kerala is based on the major components - 1. Existing used water management practices, and 2. Public Health and Environmental risk profile of the town

Toilets: Toilets are being used by all the sections of the population, Containment: Single pits are the predominant containment system in pilot towns. Despite statistical data suggesting a higher prevalence of septic tanks in Kerala, household surveys revealed that residents often misunderstand the difference between single pits and septic tanks. Many households using single pits incorrectly label them as septic tanks, describing systems with open bottoms made of laterite or bricks, and believing that wastewater infiltration is a characteristic of septic tanks. Detailed household discussions confirmed that most houses rely on single pit systems. Septic Tank Usage in Coastal and Low-Lying Areas: The usage of septic tanks is prevalent in coastal regions and low-lying areas, where high tides and elevated groundwater tables influence wastewater disposal systems. Size of containments are highly unstandardized at HHs varying from 1000 -8000L capacity.

Emptying and Transport of Septage - Tankers are used in urban areas and places near to urban settlements and collected faecal sludge is buried or dumped in open areas in most cases, In Kadappuram, sanitation worker with a bike and pump desludge and buries the faecal sludge from the containment of households, and Usage of PPE was rare in the study area.Urban areas rely on tankers for septage transport, with high incidences of unsafe disposal practices, such as direct dumping into open areas or water bodies. Treatment of septage in all the towns except Kalpetta, Maradu and Arookutty, where septage is sent to available FSTP in the respective ULBs or nearby FSTP. Monitoring of septage collection vehicle is in practice at Maradu Municipality if the service provider is the license holder of Greater Cochin Corporation's (GCC) TSB pass. PPE usage in FSTP is minimal and septage disposal to water bodies were reported in all towns.

Greywater is mostly managed within the households and households have ample space to set up HH level greywater treatment, however the choice of method for GWM are not tailored based on the hydro-geological conditions, which may cause groundwater contamination. Households release their greywater to water body or drains when it is easy to access for them or when there is a difficulty in managing greywater through their system.

General Contamination: Irrespective of the source, the water supply on which people rely on are contaminated with faecal coliform confirming that surface water and groundwater in Kerala is heavily contaminate. These sources are unsafe for human consumption as per drinking water standards.

Contamination of Water supply sources: Among the major three water sources- piped water, open wells and bore wells, depending on open wells are at high risk for human health. They are highly contaminated with faecal coliform. Faecal coliform levels in piped water and bore wells are nearly identical, indicating a widespread issue with groundwater and water supply infrastructure. Contamination of bore wells signals severe groundwater pollution. Piped water reaching at the user end is not safe for drinking, which emphasis the end for proper water treatment and much more safer water distribution which can control the contamination very effectively.

Root Cause – Improper Containment Systems: In Kerala, most households use single pits instead of proper septic tanks, causing widespread contamination. These improperly maintained pits have led to the infiltration of contaminants into surface and groundwater sources. The prolonged use of such inadequate containment systems has significantly contributed to the state's water pollution. Environmental Risks: Wastewater and greywater disposal in Kerala is causing significant environmental degradation, particularly in ecologically sensitive areas. River water and canals are at high risk, with water samples revealing high levels of faecal coliform contamination.

Strategy 1: Classification of towns broadly may fail in the Kerala context, Strategy 2: Moving from city-level classification to microplanning in UWM planning, This is ward level planning by selecting the highly densely packed wards and hotspot wards where water pollution is prevalent, and Strategy 3: Risk profiling leads to decision on the priority for the project planning process. The framework for replication of the strategy. The Used Water Management (UWM) strategy presents a transferable methodology for comprehensive water management analysis across different states. By employing detailed primary data collection and ward-level microplanning, the approach enables precise understanding of local sanitation challenges. The strategy offers a replicable blueprint for developing sustainable sanitation solutions tailored to specific regional conditions.

Climate Change Interaction with Urban Water Cycles: A Water-Energy-Climate Nexus Perspective for WASH Governance

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Climate change is disrupting the global water cycle, intensifying the frequency and severity of floods, droughts, and heatwaves. These changes increasingly burden water, sanitation, and hygiene (WaSH) systems, which are pivotal to ensuring public health and climate resilience. However, the prevailing response strategies often depend on energy-intensive adaptations that inadvertently exacerbate the existing issues of operational and financial viability as well as the greenhouse gas (GHG) emissions from water sector. Such outcomes reflect the fragmented governance and policy silos that hinder a systems-based understanding of the problem.

Through a systematic literature review, this study investigates the cascading impacts of climate change on WaSH systems, unraveling the feedback loops that link water, energy, and climate dynamics. The analysis highlights how interconnected vulnerabilities within the water-energy-climate nexus often drive unintended consequences, creating additional challenges for sustainability. By identifying these linkages and their cascading effects, the study underscores the urgent need for policy frameworks that integrate both mitigation and adaptation strategies. The findings provide critical insights to guide climate-resilient development pathways for WaSH systems, emphasising solutions that minimise environmental footprints without compromising their core functionality.

Analysing the Scaling up of Climate Resilient Non-Conventional Sanitation Solution in Maharashtra

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The world is not on-track to meet the SDG sanitation targets, necessitating innovative, non-conventional solutions will be needed to achieve universal coverage of climate resilient WASH services. Non-conventional sanitation solutions for offer several advantages over the conventional solution. They are financially economical, less water intensive, are faster to implement, modular and more resilient. Despite these advantages, decentralised treatment remains limited to pilots and institutional settings with limited city-wide application except Bengaluru. Other alternatives like urine diverting dry toilets, container-based sanitation, are not feasible in dense urban settlements and/or not culturally acceptable everywhere. On-site sanitation systems (OSS) like pits and septic tanks have been the most popular, millions of toilets connected to OSS have been constructed after (Kalbermatten, Julius, and Gunnerson 1982) found them equivalent to sewer system in protecting public health. The recognition of faecal sludge management (FSM), that is, collection, conveyance, treatment of faecal sludge contained in OSS, as an acceptable alternative has the potential to convert such toilets from basic sanitation to safely managed sanitation, the ultimate step on the sanitation ladder. Importantly, unlike decentralised treatment it has gained traction in India with nearly 1000 cities in the process of implementing faecal sludge treatment plants (FSTPs) including more than 300 from Maharashtra.

This study analyses the scaling up of FSM in the state of Maharashtra where more than 200 cities have implemented FSTPs, and another 100 cities are planning them. It employs a qualitative case study with embedded units as research method. The state level support is established by analysing the content of numerous publications of the Government of Maharashtra and its knowledge partner. The response of city governments is analysed through case studies of four cities spread across three administrative divisions and four districts. The fieldwork was conducted in early 2022. The enabling environment for sanitation planning comprising of eight dimensions, viz., policy. Legislations, organisations, monitoring, regulations, finance, knowledge management, and socio-cultural acceptance was employed as an analytical framework.

An analysis of numerous GoM's initiatives finds a support spanning all the eight dimensions of enabling environment. Most significant amongst them are policy, organisations, and knowledge management. GoM conveyed a clear roadmap of improving sanitation through the ODF, ODF+ and ODF++ framework. Later, it bypassed the need for each ULB to prepare a detailed project report (DPR) by pre-approving FSTPs with required design details for 311 cities. Its decision to co-locate FSTPs with solid waste dumpsites saved the time and effort to identify land parcel which is often challenging. The choice of simple technology also enabled ULBs to implement them using the usual EPC method. Further, parallel developments in SWM, also because of a similar push by the GoM also facilitated implementation of FSTPs.

On the organisations front, GoM's partnership with a knowledge partner to establish a technical support unit (TSU) at the GoM's secretariat was key. It helped that the ULBs owned the mandate for sanitation service provision and the state government agencies recognised their role being limited to supporting ULBs. The knowledge partner came out with several guidelines to support ULBs plan, implement and operate FSM services. This knowledge was taken to ULBs through capacity development workshops held at divisional levels. The workshops also included an element of peer-to-peer learning and ULBs creating their own action plans. Initiates of the Union Government also played a part – Swachh Survekshan, the annual ranking exercise was particularly encouraging. The certifications, potential recognition at the national level and coverage of improvement by the media enthused local governments to implement FSM.

Of course, the support from the GoM wasn't fool proof. A revised Government Resolution (GR) with revised FSTP capacities was necessitated as the original one didn't account for scheduled desludging and population growth. The GRs also didn't account for existing facilities like in Sangamner and on-going sewerage projects. GoM didn't fund any infrastructure, instead ordered local governments to use part of its untied grants. Aarrangements to regulate treatment performance are highly inadequate and not enforced. Guidance for reuse, particularly of treated solids was found lacking. Consequently treated solids were simply being stored or co-composted without adequate safety measures. Finally, there was no effort from the GoM to increase demand for emptying services – necessary for sustenance of FSM services.

The role of proactive local governments cannot be undermined. Sinnar and Sangamner had implemented a FSTP even before GoM's resolution dated 8th November 2019. Similarly, Alandi had be co-treating faecal sludge at a STP of neighbouring city before GoM's resolution dated 15th December 2018. Karjat on the other hand, commissioned a FSTP within 4 months of the GoM's resolution. With support of a knowledge partner (which later formed a TSU at the GoM's secretariat) Sinnar initiated scheduled desludging, introduced sanitation tax, involved private service providers and self-help groups in operating services and maintaining the FSTP.

The role of GoM's knowledge partner also needs to be acknowledged. Besides drafting GoM's policies, strategizing, and taking the required knowledge to local governments, it has also been monitoring implementation and supporting local governments overcome challenges.

However, the scaling up of FSM Maharashtra remains work in progress. Nearly 100 cities are yet to implement FSTPs because of issues with land. Even where it has been implemented, getting adequate and regular supply to the FSTP remains a challenge like in the city of Karjat. The backward and forward linkages with other components like scheduled desludging, regulations for reuse of treated end-products, etc. either need to be established or strengthened. Finally plugging FSM into urban governance functions like monitoring, regulations, and taxation remains unfinished.

The scaling up of FSM in Maharashtra thus offers insights to the kind of multi-dimensional support and time commitment needed to test and scale-up non-conventional solutions. At the same time, the scale-up raises critical questions about the role and ability of local governments in deciding its priorities, their relationship with the state government, and the sustainability of externally driven solutions.

Sanitation on the edge - Choices in slums amid climate extremes and urban vulnerabilities

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In slum settlements across the Global South, the nexus between housing materials, sanitation systems, and climate extremes such as heatwaves, floods, and cyclones illuminates the profound inequities that pervade urban resilience. These informal communities, typically situated in vulnerable urban fringes, bear the brunt of climate-induced risks. These risks intensify already precarious sanitation and hygiene conditions, deepening existing inequalities. As cities grow and urbanization accelerates, the lack of adequate infrastructure in these marginalized communities poses an urgent challenge to achieving sustainable, equitable development particularly in the realm of Water, Sanitation, and Hygiene (WASH). This research seeks to unearth the root causes of the sanitation crisis in slums, focusing on how housing design and construction impact sanitation practices and the broader resilience of these communities to climate extremes.

The research examines how vulnerabilities such as roofs that trap heat or flooring that is prone to flooding determine the design and adoption of sanitation systems in informal communities. Additionally, it investigates the coping strategies these households employ during climate-induced crises. By unpacking these interactions, the study aspires to identify scalable, sustainable solutions that weave together resilient housing and sanitation systems, ensuring an inclusive and climate-resilient urban future for the most vulnerable populations.

The research underscores the need to address the intricate relationship between housing, sanitation, and climate resilience in informal settlements. The findings of the study reveal that in slums, housing materials are inextricably linked to sanitation choices. In flood-prone areas, for example residents often rely on makeshift, informal sanitation solutions ranging from open defecation to shared community toilets which are inadequate for long-term health and well-being. The challenges posed by floods and inadequate infrastructure push people further into vulnerability, with waterborne diseases becoming rampant during the monsoon season. In heat-prone areas, sanitation solutions are constrained by limited water availability, leading to the adoption of low-water technologies or, in many cases, a reliance on unsafe practices. In cyclone-prone zones, traditional housing structures often built from fragile materials cannot withstand extreme weather, leading to displacement and further complicating access to safe sanitation.

A Case for Mainstreaming Valuation of Ecosystem Services in the Urban Sector

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Urban areas and regions depend upon the transaction of a range of benefits and affordances– these contribute economic, cultural, and bio-physical (health and wellbeing) values for resident populations. Collectively taken, these benefits have been termed as Ecosystem Services, a concept that captures the dependence upon natural fluxes and functions that operate at the ecosystem-level. These include the freshwater-, Nitrogen- and Carbon-cycles among others which play a role in the existence, and sustenance of all life forms in a given place and time. Nearly two dozen Services are grouped under four types – representing the sum total that undergird social and economic activities. Further, In the context of present-day environmental crises, these Services are seen as critical to human well-being, and urban resilience in an emerging literature (see for instance, Gómez-Baggethun et al. in T. Elmqvist et al. (eds.),2013). Importantly, there is recognition that future planning be tasked with reducing ecological-footprints of cities. These are characterized as 'debts' which have hitherto been extracted from peripheries and countryside/rural populations and have over time lead to an erosion of the capacity of the ecosystem to sustain terrestrial life. Concerns over excessive groundwater extraction, and deforestation can be cited as general examples, while finer grain analyses are needed to assess impacts at various locales. Thus, current debates in scholarship note that more attention to be paid to 'the ecology of cities' characterized by interdisciplinary and multiscale studies with a social-ecological systems approach (Grimm et al. 2000 ; Pickett et al. 2001). These trends underscore the importance of Ecosystems Services and the concept is useful to integrate existential and economic values with the material, cognitive, and sustenance affordances provided by nature and its processes, which are necessarily finite and increasingly under threat. Though there is wide acceptance of their significance, these are seldom considered in economic analyses, and conventional planning has regarded these generally as externalities. The combination of rapid growth of cities and marginalization of these critical services interact with stresses accompanying global climate change and pose major threat to sustainability and the resilience of communities and cities. Valuation of Ecosystem Services returns the services externalized in conventional economic analyses as the basis of all economic activities, and prioritizes the health of Ecosystems and the continued availability of their services for economic sustainability. The paper outlines the emerging understanding of Ecosystem Services in recent studies, and their continuing significance for human well-being and economic growth. It explains how the marginalization and subsequent decline in these Services pose significant threats to human wellbeing, and addressing this marginalization is both necessary and urgent. Assuming a pragmatist stance, the Paper outlines the discursive ways in which Ecosystem Services can be included in the urban sector, arguing for their valuation as a means of ensuring attention on their maintenance. These ways are examined for their strengths and weaknesses, and the paper outlines the useful ways in which these valuations can be pivotal to resilience in the Urban Sector.

Enhancing Sustainability of- Rural Water Supply in Sri Lanka's Plantation Sector: The Role of Estate Worker Housing Cooperative Societies (EWHCS) as Community-Based Organizations

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Sri Lanka has many estates covering about 775,000 hectares. They are mainly in central parts of the country. The above estates mainly provide tea, rubber and coconut for the export market. They were originally owned by many foreigners and wealthy locals, but in 1973 the government nationalized them. Since then, the government adopted various mechanism for the management of them and finally in the 1990s, estates were again handed over to 23 private companies on a lease basis to manage them on behalf of the government. The population in the estate sector closes to one million, and many members of families are employed in the estates. They are living in small houses and regularly face the lack of basic facilities. As many estates have small gravity sources of water, their water needs are mainly fulfilled through them. With the increasing population and depleting water resources, there are various issues that emerged in managing the water supply in estates. Therefore, community managed rural water supply systems prevailed in other parts of the country are adopted for estate water supply management. This paper describes a new approach of managing them with the existing corporative societies in estate sector. The study aims to identify and validate the most effective community-based organization (CBO) mechanism to manage and sustain rural water supply systems in Sri Lanka's plantation sector. Specifically, it seeks to explore the role of Estate Worker Housing Cooperative Societies (EWHCS) as a leadership model for CBOs, addressing the challenges of water accessibility, operational sustainability, and community ownership in the unique socioeconomic and geographic context of plantation communities.

Research Questions/Problems Addressed

1. What are the challenges faced by rural water supply systems in the plantation sector of Sri Lanka in terms of sustainability, access, and management?

2. How effective are the various community-based organization mechanisms trailed in these settings?

3. Why does the EWHCS leadership model emerge as the most suitable structure for managing rural water systems in plantation areas?

4. What strategies can further enhance the efficiency and sustainability of water supply systems under the leadership of EWHCS?

The study employed a mixed-method approach to comprehensively evaluate rural water supply mechanisms: Quantitative Analysis - Data from operational water systems (e.g., service coverage, financial performance, and system reliability) were analyzed to assess the effectiveness of different CBO models, Qualitative Insights - Interviews and focus group discussions were conducted with community members, EWHCS representatives,

estate management, and local government officials to understand perceptions, challenges, and the benefits of various mechanisms, Comparative Evaluation - To identify strengths and weaknesses, case studies of water systems managed by EWHCS versus other models (e.g., independent CBOs or estate management-driven models) were conducted.

Challenges in Water Supply Systems: Limited Technical Expertise: Many independent CBOs lacked the technical and managerial capacity to sustain water supply operations, Low Community Participation: The absence of robust leadership often resulted in poor engagement and accountability among community members, Financial Instability: Non-EWHCS-managed systems frequently struggle to collect tariffs and cover up operational cost.

Effectiveness of EWHCS Leadership - EWHCS provided a structured and trusted leadership model with established governance mechanisms that encouraged community participation. These societies effectively leveraged their experience in financial management and collective decision-making to sustain water supply systems. EWHCS leadership ensured transparency, accountability, and equitable distribution of water services, addressing longstanding inequalities in plantation communities. Sustainability Outcomes: Systems managed by EWHCS demonstrated higher reliability and longer operational life due to proactive maintenance and better financial planning.

Water access and service satisfaction levels were significantly higher in estates where EWHCS led CBO are in operation. The findings underscore the pivotal role of EWHCS in overcoming key challenges faced by rural water supply systems in plantation areas. Their structured leadership fosters a sense of ownership, accountability, and community participation, which are critical for long-term sustainability. Policy Implications - These findings suggest that future rural water supply projects in the plantation sector should prioritize integrating EWHCS into CBO mechanisms. Policymakers and stakeholders should provide technical and financial support to strengthen the capacity of EWHCS to manage water systems effectively. Replicability - The success of EWHCS-managed systems offers a model that can be adapted to similar socio-economic contexts in other rural settings. Sustainability Strategy - Supporting EWHCS through capacity building, resource mobilization, and strategic partnerships can enhance their ability to meet growing water demands and climate resilience challenges.

Waste waterscape inducing inequalities Informal areas: A Case of NCT Delhi

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Wastewater (used water) is increasingly recognized as a valuable resource in today's context, where freshwater availability is limited, yet the demand for it continues to rise. The "wastewaterscape" of an urban area encompasses both the technical aspects of wastewater management and the social and political dynamics that influence how wastewater is generated, distributed, and treated in urban environments. Various stakeholders are involved in the service delivery and decision-making processes related to the provision of water, sanitation, and hygiene (WASH) services. In many informal settlements in the NCT of Delhi, these areas are often located along natural drainage channels, where a significant amount of untreated wastewater is directly discharged in these drains. This practice ultimately leads to the contamination of the Yamuna River. The current governance framework, characterized by socio-political factors favoring abundant water provision to these settlements, but the lack of appropriate wastewater infrastructure (drainage) and treatment facilities, gives rise to health risks and hygiene issues within these settlements, contributing to conflicts among residents and local leaders. The study is based on the primary study (interviews and narratives) conducted in various JJ Clusters around the NCT of Delhi. This paper aims to explore how the existing wastewaterscape in informal areas perpetuates inequalities in access to water, sanitation, and hygiene. It examines the role of the existing wastewaterscape in creating disparities within the WASH system and recommends strategies to mitigate these inequalities through the interventions in wastewaterscape for inclusive urban planning.

Lease Financing Mechanism for Scaling Up- Small and Medium Sanitation Entreprises for Expansion of Pit Emptying Service Delivery in Low Income Areas of Lusaka: Pespectives from Lusaka, Zambia

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Emptying Services in Lusaka are provided through performance based contracts with private operators. The private operators were faced with one challenge of inadequate capacity to empty and transport sufficient volumes of Faecal Sludge (FS) to meet the targets set in the contracts. This was due to the operators using old trucks that frequently broke down as well as the lack of proper tools for emptying pit latrines either manually or mechanically. Thus to improve their operations and expand service provision to all LICs, equipment was procured for them on a Hire to Own agreement based on the contracts with LWSC. The study uses both primary and secondary data. The designed mechanism for hire to own is used as the framework for this paper. Further secondary data and experiences in implementing this mechanism was used to construct a logical narrative on the designing and implementing the hire to own mechanism for increased access to finance for enhanced service delivery. Participating in designing and execution of the hire to own mechanism, observations are also used for construction of the narrative and sharing of experiences and lessons.

The financing mechanism targeted provider operators who have signed performance based contracts with LWSC to provide pit emptying services in LICs of Lusaka. This was done because the demand for pit emptying services was high in the LICs, however, the lack of sufficient equipment was hampering efficiency and expansion of services. This was mainly due to the operators using old trucks which frequently broke down and in some instances others had no trucks of their own and had to hire trucks from car hire companies. The private operators had no capacity to buy the required equipment to ensure effective service provision. Borrowing was the only option, however, most lending institutions in Zambia are not willing to lend their money to SMEs due high risk of default. This prompted LWSC to purchase the equipment to give them to the operators on a Hire to Own agreement. Under this agreement, the operator pays a hire to own fee to LWSC which is deducted from their monthly payment claims or paid directly to the utility's account. Monitoring data indicates that there has been enhanced efficiency improvement of 68% for faecal sludge volumes delivered at the treatment facility from the time the equipment was purchased and given to the operators.

Access to finance by small and medium scale private operators involved in sanitation service delivery has the potential to enhance sanitation service delivery and contribute to meeting the sanitation needs of cities. A financing mechanism such as the OWN TO HIRE financing mechanism for investing in equipment for service delivery is essential in addressing the financial access challenges and increase capacities for small scale private operators who cannot access bank guarantees for financing their capital investment. It recommended that such a mechanism is scaled-up to other private operators who have challenges in accessing finance for capital investments.

Investment in WASH Sector in South Asia: A Review from FANSA's lens

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As the world progresses toward achieving the Sustainable Development Goals (SDGs) by 2030 it is utmost essential to analyze the current investment trend in WASH across South Asia to understand where are in terms of progress made and addressing the unmet targets, particularly at the current scenario where almost all the SA countries may not be able to achieve their SDG commitments. Despite increased awareness, capacity building and understanding of the needs of investment to accelerate progress, gaps in financial investment still persist. To address these challenges, Freshwater Action Network South Asia (FANSA) under the project of Rising for Rights: Strengthening Civil Society Networks in South Asia to achieve SDG 6 conducted a study involving its National chapters across SA i.e. Bangladesh, Bhutan, India, Maldives, Nepal, Sri Lanka and Pakistan except Afghanistan. This study sought to analyze financing trends, assess fund utilization, evaluate investment gaps, and identify challenges in achieving SDG 6 across South Asia.

The study was conducted with a more qualitative technique, adopting tools like Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and interactions with the key stakeholders within the countries. Secondary data from national, regional, and global reports were referred to validate the collected information from the respective countries. Besides, multi-stakeholder consultation workshops were conducted for validation in the respective countries. Qualitative Data Analysis (QDA) technique has been adopted for the analysis of the data and information generated in each country. After synthesizing all these data an information collected from all the countries across SA, primarily from the ground, literatures, and from key stakeholders amidst the multistakeholder workshop, the findings were synthesized to a consolidated report "Review of Sector Investment in WASH in South Asia: A Synthesis Report". The study revealed that between 2015 and 2022, access to basic water services in South Asia improved marginally from 89% to 93%. However, rural areas remain underserved, with basic service access improving from 30% to 67%, while urban areas maintained high coverage at over 95%. Safely managed services remain either insignificant or absent across the region. In sanitation, basic sanitation service coverage rose from 22% to 27%, while safely managed sanitation services improved from 35% to 49%. Rural areas achieved notable progress in safely managed services (35% to 53%), while urban areas saw basic sanitation access increase from 36% to 40%.

The status of financing for sanitation in South Asia is complex and varies significantly across countries in the region. However, following three sources financing for sanitation in SA prevails i.e. 1. Public Funding: Government budgets for sanitation have been increasing but often remain insufficient to meet needs. Countries like India have allocated substantial resources to improve sanitation infrastructure, yet disparities persist, especially in rural areas, 2. International Aid: Many South Asian countries benefit from international development assistance for sanitation projects from organizations like the World Bank, UNICEF, and various NGOs. However, funding can be sporadic and project-focused rather than ensuring systemic improvement, and 3. Private Sector Engagement: There has been a

growing recognition of the role of the private sector in sanitation financing, particularly in promoting innovative sanitation technologies and solutions. However, effective public-private partnerships still need to be fully realized.Finance in WASH demonstrated varies progress in South Asia. India led with its financing score increasing from 32 in 2017 to 73 in 2023, reflecting enhanced investment and prioritization. Bangladesh, Maldives, and Pakistan achieved medium-high financing scores, while Nepal and Sri Lanka remained at medium-low levels. Bhutan lacked sufficient data for analysis. Achieving SDG 6 requires substantial investments, particularly in countries like Nepal, Pakistan, and Bangladesh, which need over USD 250 per capita annually which is more than 2% of GDP. Allocation trends remain inadequate, hindered by inefficiencies in fund utilization. Besides, many countries are struggling with outdated infrastructure and require significant investment in both sanitation facilities and waste management systems. Furthermore, equity in WASH investments remains limited. Vulnerable groups, including women, people with disabilities, and populations in remote or informal settlements, are insufficiently targeted in financial plans. Currently none of the countries accounted to address the issues of WASH pertaining to the issues related climate induced disaster and effects of climate change, and this possibly demand high investment further to what has been estimated.

To achieve SDG 6 targets, it is crucial to strengthen data systems by developing comprehensive mechanisms for data collection and analysis. This will ensure accurate funding estimations and identification of marginalized groups, enabling equitable access to WASH services. Merely increasing funding is insufficient; funding approaches must incorporate sustainability and address the complexities of meeting SDG standards. Techno-financial accountability and government capacity need significant improvement to enhance fund utilization and regulatory frameworks. Strengthening these aspects will ensure more efficient use of resources and accountability across the WASH sector. Furthermore, better coordination and coherence among water-related sectors are essential to minimize inefficiencies and achieve integrated outcomes. Lastly, prioritizing equity and inclusion through targeted strategies and adequate data support will address the needs of marginalized and underserved populations, ensuring no one is left behind.

Financing Climate-Resilient Urban Water Reuse Infrastructure: A Strategic Framework for Sustainable Water Management

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Urban water management has reached a critical juncture, characterized by unprecedented challenges of resource scarcity, infrastructural inefficiency, and climate vulnerability. This research presents a comprehensive framework for addressing these complex issues through innovative financing of water, sanitation, and hygiene (WASH) infrastructure, with a specific focus on sewage treatment plant (STP) water reuse systems. The study emerges from a critical examination of urban water systems, revealing significant infrastructural limitations that impede sustainable water management. Through a rigorous mixed-methods approach, the research integrated quantitative infrastructure performance analysis, sophisticated financial modeling, and comprehensive policy landscape assessment.

The methodological framework systematically evaluated existing sewage treatment technologies, exploring their efficiency, scalability, and technological adaptability while simultaneously investigating innovative financing mechanisms. Economic analysis formed a cornerstone of the research, demonstrating compelling financial rationales for water reuse infrastructure. Comparative cost metrics revealed substantial economic differentials, with freshwater costing approximately ?12 per unit, contrasted against treated wastewater production costs of approximately ?45 per unit. This economic disparity underscores the potential for strategic infrastructure investment and provides a robust economic argument for systematic water reuse implementation. The research developed a multifaceted financing strategy that transcends traditional infrastructure funding models. By integrating blended finance approaches, green bond structures, municipal infrastructure investment funds, and performance-linked financial instruments, the study proposed a comprehensive mechanism for overcoming financial barriers to water infrastructure development. These innovative financing models create pathways for substantive investment in climate-resilient water management systems. Key contributions of the research include a detailed technological recommendation matrix, adaptable policy intervention guidelines, and robust economic models demonstrating the financial viability of water reuse systems. The framework emphasizes a multi-stakeholder approach, engaging governmental agencies, infrastructure developers, financial institutions, and community stakeholders in a collaborative problem-solving strategy.

The study's significance lies in its holistic approach to urban water management challenges. By synthesizing technological capabilities, economic feasibility, and policy interventions, the research provides a strategic roadmap for transforming urban water infrastructure. The proposed framework not only addresses immediate infrastructural needs but also offers a scalable model for climate-resilient urban water systems. Principal findings highlight critical barriers to water reuse infrastructure development while simultaneously proposing innovative solutions. The research demonstrates the potential for systematic improvements in urban water management, promoting more sustainable, resilient, and economically viable water infrastructure strategies. By bridging technological innovation, financial sustainability, and policy reformation, the study contributes substantively to the

emerging discourse on climate-resilient urban water management. The methodology presents a transformative approach to addressing complex urban water challenges, offering a comprehensive solution that extends beyond traditional infrastructure development paradigms. It provides stakeholders with a nuanced understanding of the interconnected technological, economic, and policy dimensions critical to sustainable urban water management.

Urban Rural Convergence in FSSM: A case of Gandhidham and Anjar

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More than half of India's households depend on onsite sanitation systems. The National Fecal Sludge and Septage Management (FSSM) policy prompted Urban Local Bodies (ULBS) to adopt FSSM frameworks and construct treatment plants. Furthermore, there is limited on-ground implementation of the same. Yet most of the rural areas could not get the policy implemented due to several factors like inadequate infrastructure, funds or capacity. Furthermore, the situation worsens as cities prioritize centralized servers as an alternative to avoid the challenges faced in decentralised usedwater management, This intensifies particularly in semi-arid regions with limited water resources. This research explores the possibility of Urban-rural convergence in FSSM as an option to address the

issue by utilizing the existing infrastructure in urban areas to its full capacity and making the facilities available to the rural areas with limited infrastructure. Considering parameters like water scarcity and coastal proximity, the cities of Anjar and Gandhidham were taken up, and the sanitation value chain was analysed in both urban and rural areas. A comprehensive framework was developed to establish a systematic approach to periodic desludging at the Urban Local Body (ULB) and Gram Panchayat (GP) levels. This framework outlines the operational procedures for desludging and addresses subsequent steps within the sanitation value chain, including transportation, treatment, and safe disposal of sludge. The framework emphasizes a holistic integration of key stakeholders to ensure sustainable management practices. Furthermore, the study also documents the explains of a prevailing used water market in the cities.

Safe Management of Faecal Sludge using enhanced drying on drying beds

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The main goal of this study was to develop an innovative mechanism to enhance the treatment of faecal sludge in Lusaka, Zambia. Specifically, the research aimed to address the critical challenges posed by inadequate sanitation facilities in low-income areas, where approximately 70% of the city's population relies on onsite sanitation systems, such as pit latrines. Given the increased volumes of faecal sludge being generated, there is an urgent need for improved treatment systems that can efficiently manage and process this waste. The study focused on utilizing enhanced drying beds equipped with heating pipes to accelerate the drying process, thereby improving the overall treatment capacity for faecal sludge.

Research Questions/Problems Addressed:

1. Capacity Limitations: How can the treatment capacity for faecal sludge be increased in the face of limited existing facilities and resources in Lusaka?

2. Efficiency in Drying: What innovative mechanisms can expedite the drying process of faecal sludge to improve management efficiency and reduce health risks?

3. Sustainability: How can financial sustainability be achieved through innovative sludge treatment practices to ensure ongoing operations and maintenance?

The study employed a practical and experimental design, focusing on the construction and testing of a pilot facility dedicated to enhanced drying of faecal sludge. This facility was specifically engineered to assess the effectiveness of heating pipes integrated into drying beds. The methodology involved the following steps: 1. Design and Construction: A pilot facility was designed to incorporate enhanced drying technology, using heating pipes to improve the drying process of faecal sludge from pit latrines, 2. Testing and Analysis: The pilot facility was subjected to rigorous testing, with pit latrine sludge being screened and dried. Proximate analyses of the sludge were conducted to evaluate various parameters, including moisture content, ash content, volatile matter, fixed carbon, and gross calorific value and 3. Comparison of Drying Methods: Results were obtained from both normal drying and the enhanced drying processes to establish effectiveness and efficiency differences.

The research yielded several significant findings that underscore the potential of the innovative drying mechanism - 1. Moisture Reduction: The enhanced drying beds significantly reduced the moisture content in faecal sludge compared to traditional drying methods. For instance, the moisture content in heated sludge dropped to 14.28%, compared to 18.26% in normally dried samples. 2. Improved Calorific Value: The gross calorific value of the treated sludge increased with the enhanced drying method, indicating a higher energy potential for the dried material. For

example, the gross calorific value for heated sludge reached up to 3905 Kcal/Kg, compared to 3746 Kcal/Kg for normal drying. 3.Operational Efficiency: The study demonstrated that the frequent harvesting of dried sludge created space for additional raw sludge, thereby improving the overall treatment capacity of the system. This continuous process helps manage the increased volumes of faecal sludge more effectively.

The findings from this study provide valuable insights into the management of faecal sludge in urban settings like Lusaka. The results highlight the necessity for innovative solutions to tackle the sanitation crisis faced by low-income communities - 1. Enhancing Treatment Capacity: The significant reduction in moisture content and the improvement in calorific value demonstrate that the enhanced drying mechanism can effectively increase the treatment capacity of existing facilities. This is crucial in a context where the demand for sanitation services far exceeds current capabilities, 2. Health and Environmental Impact: By improving the efficiency of faecal sludge treatment, the study contributes to reducing public health risks associated with untreated waste. Properly treated sludge minimizes the chances of contamination and disease spread, particularly in densely populated areas reliant on onsite sanitation systems, 3. Financial Sustainability: The project proposes pathways to financial sustainability, emphasizing the importance of revenue generation through gate fees from service providers and potential partnerships with private companies for value-added products. By branding and packaging excess manure for sale as carbonized briquettes, the project can create an additional revenue stream that supports operational and maintenance costs and 4. Future Applications: The study's approach can be scaled and adapted for similar urban settings facing sanitation challenges. The principles demonstrated can serve as a model for developing innovative treatment solutions in other cities across Africa and beyond, where inadequate sanitation infrastructure is a pressing issue.

In conclusion, this research not only addresses immediate treatment challenges in Lusaka but also contributes to broader discussions on sustainable sanitation practices. By optimizing existing treatment methods through innovative technology, the study offers a pathway toward achieving inclusive sanitation services that benefit low-income populations, ultimately supporting the health and well-being of communities. The implications of this research extend beyond Lusaka, presenting a scalable solution that can inspire similar initiatives globally.

Kinetics Of Chemical Oxygen Demand (Cod) Removal Of Anaerobic Baffle Reactor At Wastewater Treatment Plant

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This project presents an in-depth assessment of the kinetics of COD removal of anaerobic baffle reactor (ABR) at wastewater treatment plant (WWTP) case study of Kathmandu University, Nepal. The study aims to evaluate the efficiency and performance and kinetic model of the wastewater treatment. Anaerobic baffle reactors (ABRs) have emerged as effective components in wastewater treatment plants (WWTPs) for organic matter removal, particularly in developing countries due to their simplicity and low operational costs. Understanding the kinetics of chemical oxygen demand (COD) removal within ABRs is crucial for optimizing their performance and enhancing treatment efficiency. This study investigates the kinetics of COD removal in an ABR system at a WWTP, focusing on the factors influencing the process and the associated reaction rates. Total number of samples per day = 10 sampling points x 1 sampling times per day = 10 samples. Total number of samples per week = 10 samples x 3 days/week = 30 samples. Total number of samples for the study (4 weeks) = 30 samples x 7 weeks = 210 samples.

The research methodology involved a comprehensive review of literature to establish theoretical frameworks for wastewater and treatment kinetics of COD removal at ABR. Field investigations, characteristics, and experimental data will be collected from inflow, compartment and outflow of full-scale ABR unit treating wastewater at a WWTP over a specified period. The COD removal kinetics was analyzed using various mathematical models, including first-order and second-order. Factors such as influent COD concentration, hydraulic retention time (HRT), temperature, and mixing intensity were considered in assessing their impact on COD removal rates. Therefore, the COD concentration of the effluent was meet the standard, and the total removal efficiency was good. With the operation of the reactor continuously, the activity of the sludge would be higher, and the COD of the effluent of the good condition. The first and second-order kinetics had high regression coefficients (R2 values) of 0.977 and 0.802, respectively. This indicates that the first order regression model, with an R2 value of 0.977, provides a better fit compared to the second order model. The average values for the first-order Co-Ct/HRT ranged between 166.91 and 156.01, while Ct values spanned from 278.04 to 54.12. For the second-order, the average values ranged between 1.65 and 0.33, and 1/Ct values ranged from 0.0167 to 0.0038.

Exploring Safe Utilization of Sludge of Wastewater Treatment plant for Resource Recovery

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The treatment and disposal of sludge from wastewater treatment plants (WWTPs) present significant environmental and economic challenges, with sludge volumes expected to increase globally due to urbanization and industrial activities. Although sludge is traditionally considered as waste, the utilization of sludge from wastewater treatment plants has gained increasing attention due to its potential for resource recovery, environmental sustainability, and cost efficiency as sludge contains valuable organic matter, nutrients, and trace elements that can be repurposed, reducing the environmental footprint of wastewater treatment facilities. This study explores sustainable approaches for the safe utilization of WWTP sludge, focusing on resource recovery opportunities that can reduce waste and generate valuable by-products. Laboratory studies have played a crucial role in exploring how these sludges can be processed and applied in real-world settings, providing insights into their composition, dewatering capabilities, pollutant concentrations, and energy potential.

The high organic contents, nitrogen (2.1%), phosphorous (1.7%), and potassium (0.709%) value of treated sludge indicated that stabilization techniques, such as composting and biochar production, could improve soil fertility, enhance plant growth, and serve as a sustainable material to improve soil structure and increase crop yields. Additionally, chemical assessments in this study ensure that the material does not pose environmental risks, such as leaching harmful contaminants, including heavy metals, such as lead, mercury, arsenic, cadmium, etc. The laboratory results indicated that there are no helminth ova and E. coli present within safe limits, making the compost safer for downstream use. Despite the potential use based on our laboratory test results, the transition from laboratory insights to field applications also involves addressing practical challenges such as transportation, regulatory compliance, and public perception for its utilization as soil amendments or fertilizers. Continuous research, pilot projects, and collaboration between industry and regulatory bodies are needed to ensure that sludge can be utilized safely and efficiently, benefiting both the environment and the economy.

Evidence Based Decision Support Tool For Implementing IWRM At Schools

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Government schools in the Deccan region of India are grappling with water security issues. The absence of proper wastewater management exposes children to health risks, while inadequate water supply for sanitation leads to unhygienic conditions, contributing to increased dropout rates, particularly among girls. Despite schools managing water supply, the lack of wastewater management poses health risks, and the potential for greywater reuse remains unexplored. To mitigate health risks associated with poor water management in schools, we propose developing a web-based decision support tool. This tool will guide practitioners and NGOs in implementing integrated water management systems in schools. We conducted a survey of 23 government schools in urban, peri-urban, and rural areas around Bengaluru to address water management challenges. Using a combination of social science and natural science methods, we collected water quality data from greywater sources and mapped disposal sites for greywater and black water. Additionally, we assessed current sanitation habits and student attitudes towards greywater treatment and reuse. Data on available area and kitchen facilities were also gathered. By integrating insights from both sciences, we developed algorithms for a web-based decision support tool. These algorithms consider water quality, waste consumption, area availability, and intended use of treated water. This methodology enabled us to create a practical tool for implementing integrated water management systems in schools, bridging the research-practice gap and addressing water security issues effectively. Greywater disposal practices varied significantly among the surveyed schools. Three main methods were identified: soak pits, open stormwater drains, and direct release onto the ground. Of the schools surveyed, 38% discharged greywater into open stormwater drains, 50% utilized soak pits, while the remaining 12% released greywater directly onto open ground.In rural and peri-urban schools, where soak pits were commonly employed, the risk of direct exposure to contaminated greywater was mitigated, thus safeguarding the health of children. However, there remained a notable concern regarding groundwater contamination due to potential leaching of contaminants from soak pits. Given the reliance of these schools on groundwater, this poses a significant environmental and health risk. The analysis underscores the urgent need for the development of a web-based decision support tool. Such a tool would enable decision-makers to identify school-specific greywater treatment and reuse options tailored to the unique context. By providing a comprehensive overview of greywater disposal practices and associated risks, the tool will empower practitioners and policymakers to make informed decisions regarding wastewater management in schools. The AQUAWISE web-based tool offers a user-friendly solution for practitioners and policymakers to select appropriate wastewater treatment and reuse options for schools. The tool's algorithm translates minimal input data into output tables (showing treatment option with capital and O&M cost), matching school requirements regarding available area and intended water use. By utilizing this tool, practitioners can effectively tackle water security issues

The Effluent Diversion Unit

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Pit latrines are the primary sanitation solution for approximately 1.8 billion people worldwide. These latrines, designed as containment units for blackwater, frequently require desludging and treatment. This process typically involves a complex logistical chain of emptying, transporting, and centralized treatment. However, many users opt for unlined pit latrines or, when emptying pits, dump untreated fecal sludge (FS) directly into the environment, resulting in water contamination and disease transmission. Pit latrines receive a variety of inputs, including cleansing water, urine, flush water, feces, and occasionally other waste such as paper tissue, etc. Although liquid components—comprising over 95% of the flow—are largely aseptic, their mixing with pathogen-rich fecal solids creates a hazardous sludge that is unsafe for direct disposal. Regular emptying of this sludge is essential but often unaffordable, unsafe, or unavailable. Manual desludging methods, which are commonly used in underserved areas, pose severe occupational health risks to workers, often from marginalized communities, while untreated sludge frequently ends up polluting the environment.

Transporting and treating fecal sludge at centralized wastewater facilities involves significant capital and operational expenses. These challenges are compounded in off-grid settings, where such services are rarely available, leading to a cycle of unsafe waste management practices and environmental degradation. To address these challenges, we developed and tested the Effluent Diversion Unit (EDU), a liquid-solid separator designed to transform pit latrine functionality. The EDU offers a decentralized, cost-effective solution by separating solid and liquid waste streams at the source, thereby preventing blackwater formation. This innovative plastic fitting enables on-site treatment of liquid effluent and localized drying or composting of fecal solids, making sanitation systems safer, more accessible, and environmentally sustainable without requiring user behavior changes.

Waste Stream Separation: The EDU separates liquid effluent (urine, cleansing water, and flush water) from fecal solids, significantly reducing the volume of pathogenic sludge. Compact On-Site Treatment: Liquid effluent is treated on-site using a three-stage system—a settling tank, biosand filter, and leach field—all within a compact 1 m^2 footprint. Sustainable Solid Waste Management: Fecal solids can be managed through decomposition or vermicomposting, providing environmentally friendly waste recycling options. By separating and treating waste streams at the source, the EDU reduces pit latrine filling rates by up to 95%, drastically lowering desludging costs. Additionally, it decreases the size of downstream fecal sludge treatment units by 80%, cutting both capital and operational expenditures. Priced at $60–100 per unit (in Bangladesh), the EDU is an affordable, scalable solution that reduces reliance on centralized systems.The EDU is versatile, integrating seamlessly with urban sewer systems to reduce solids load and improve wastewater treatment efficiency. Its adaptability makes it suitable for diverse contexts, including urban areas, low-income communities, and humanitarian settings.

The Case Study of Moradabad Amrit Sarovar

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All across the globe, we have a problem of overcrowded cities with depleting natural resources. Bad Air quality, sewage, depleting ground Water table, biodiversity losses, drinking Water availability, polluted Waterbodies, increasing GHG emissions, sanitation & hygiene issues, depleting agricultural production and declining farm profitability, Chemicals & Antibiotics in Human food chain, floods & droughts, Water logging and so on. All these problems are the chain reaction of Water, Soil and Air getting contaminated. The available approaches in the market are trying to solve it separately, like the STP is not bothered about the air quality, SMOG towers don't understand the soil health and plantation drives don't provision for Waterbodies, usually. Since all of them are interlinked, the problem can't be solved if dealt with an approach in silos. And therefore, a holistic & sustainable nature-based solution can solve all of them in one go.

A case Study Moradabad city is often referred as the 'Brass capital' of India. Every home is involved in brass-based handicraft and both side of the city there are brass manufacturing industrial corridors. so much of metal work had its impact on the natural resources too. All Waterbodies were contaminated with effluent, Air Quality Index was bad (beyond permissible limits, above 300 since year 2017), round Water was report depleting since year 2009, major biodiversity loss was observed and every monsoon there was an outbreak of vector-borne diseases. Urban flood & Water logging was also a common phenomenon post monsoon.

Nature-based Solution for "resurrection of Native Ecology" We got a project in April 2022, for 'in-situ' rejuvenation of six Waterbodies spread across the city on the periphery, through our Nature-based Solution (NbS) that we call as 'Cownomics Technology', wherein we focus on 'resurrection of the native ecology' of the Waterbodies & wetlands with a clear objective of 'restoration of the 'ecosystem services'. As a result, the ground Water recharge was reported by August, 2022. There was steep decline in post monsoon vector-borne diseases (as observed and reported by the residents in the vicinity). They won the National Award for Best work in Air pollution mitigation (for last 360 days their AQI is recorded below 80). Return of birds, bee, butterflies and aquatic life has been observed in all ponds. And the Water quality is maintained as per IS 2296, class B category for outdoor bathing Water, as per the guidelines of National Green Tribunal(NGT). Social Benefits of NbS Approach – 1. The project makes Water available for all life forms, 2. By recharging and correction of the ground Water, we solve the Drinking Water crisis too, 3. The project ensures Water availability for agriculture, aquaculture and animal husbandry, we create livelihood opportunities as well, ensuring a better per capita income and economic prosperity, 4. By solving the Water and vector borne disease crisis, we help restoring the health of the people living in the vicinity too resulting into a better public health index and 5. By take care of Air pollution mitigation, we help all the communities in a better prosperity index.

Economic Benefits – 1. The project makes the farms go diseases, pests and weather resilient, making the farmer profitable by multiplying the yield (qualitative & quantitatively as well) and also help

the farm go chemical & antibiotic free, which mean low input and high output. This would reinstate the rural economy, 2. If the footprint of NbS goes in a national scale, a ripple effect of this would be huge saving in exchequer of ?12,500 Cr annually, 3. By solving the Water, Air and vector borne diseases problem, we also help marginalize communities to make huge savings, better health and prosperity, which means a better workforce for the country, 4. Healthy Waterbodies, ensure Water availability for industries too, which adds to the country's GDP. Healthy Waterbodies are heat sink too (absorbing 5~8?C of temperature from the vicinity), which means lowering the requirement of air-conditioning in the vicinity, amounting to huge savings in the energy requirement and nullifying the PVHI & UHI effects.A Nature-based Solution (NbS) is the key to solving the global crisis and climate catastrophes, which is holistic and sustainable as well.

Feacal Sludge Treatment by Vermicomposting Technology

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Vermicomposting technology utilizes earthworms to convert feacal sludge into nutrient-rich compost, offering an eco-friendly solution for feacal sludge management. This study explores the efficiency of vermicomposting using earthworm species, Eisenia fetida. The overall goal of Feacal Sludge Management using this vermicomposting technology is the protection of public and environmental health. The research evaluates the impact of feacal matter compositions and environmental conditions on the composting process. Results indicate that vermicomposting significantly enhances the decomposition rate and nutrient content of the final compost. The findings suggest that vermicomposting can be an effective method for managing feacal sludge, improving soil health, and supporting sustainable agricultural practices. There are some precautions to be taken such as Using plastic sheets to cover beds/heaps is not recommended because it may create a greenhouse effect causing air and gases to entrap in the vermicompost bed/heap. However overloading them can increase their temperature, which is harmful to the worms. The worms die out in the dry conditions and they simply move away when the ground becomes waterlogged. In June, July, and August during summer daily watering is ideal while in the rainy season (December to February) once a week whereas in winter every third day. In rainy weather, this can avoid the accumulation of water, and especially in areas with high rainfall during that season you will need to build a drainage channel around the heap. The results showed that for Maintenance of vermicomposting, regular monitoring is required to maintain moisture levels and ensure the environment remains aerobic. This might involve adding water or turning the compost. The Significance of Vermicomposting are huge. The balanced physical, chemical, and microbiological characteristics make Vermi castings an excellent natural plant fertilizer since it is good for improving soil structure, moisture retention, and nutrient content. Vermicomposting promotes Organic farming in gardening and sustainable agriculture. It is an ideal replacement for chemical pesticides and insecticides. It is free-flowing and easy to apply on the field thus, the farmers or the users can handle it easily without any fiasco. It has also a growing emphasis on environmental conservation and waste recycling, so it is environmentally friendly. Now globally food security has been pushed or encouraged, so that the compost is free of toxins when used in the agriculture field gives toxin and chemical-free vegetable and fruit items.

Standardization of Septic Tanks in Mahalaxmi Municipality: A Sustainable Approach to Wastewater Management

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Rapid urbanization in Mahalaxmi Municipality has intensified the demand for effective and sustainable sanitation systems. However, the lack of standardized guidelines for the design, construction, and maintenance of septic tanks has resulted in environmental degradation, public health risks, and infrastructural challenges. To combat these issues, Mahalaxmi Municipality has pioneered the implementation of ISO 24521, marking the first global application of this international standard for the management of wastewater services. This initiative is complemented by the adoption of the Integrated Municipality Information System (IMIS), seamlessly integrated with the Electronic Building Permit System, enabling comprehensive tracking and regulation of sanitation practices.

This study highlights the challenges of existing septic tank practices and underscores the transformative potential of these innovations. By aligning local needs with international best practices, the municipality's approach ensures sustainable and safe sanitation for its rapidly urbanizing population. The findings demonstrate how standardization not only enhances wastewater management but also serves as a model for municipalities worldwide to achieve long-term resilience and sustainability.

Exploring Trends and Technological Innovations in WASH Services: Discussing Challenges and Strategies for Improvement

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SDG (2015) together promote global actions for sustainable future. Of these, SDG-6 aims to provide access to water and sanitation for all. Understanding from past research, globally eight out of every ten people lack access to safe and adequate drinking water. If present improvement rates are not accelerated, 1.6 billion or more people will lack access to adequately managed drinking water by 2030. Contributions of WASH services though in-line with SDG-6, in addition to climate and environment, it faces challenges from inadequate data and limited technological innovations. In recent decades, emergent technologies, methods, and data-sharing platforms are being used to monitor the impacts of WASH interventions. These technological innovations focus on improving access and quality of these services. It is anticipated that new technologies and methods may facilitate the collection and analysis of increasingly complete and impartial data over time. This paper presents a literature review of technological innovations and an overview of technological innovations and interventions to overcome the challenges in WASH services by comparing global case studies.

Analysis the temporal change in River trajectory

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This study investigates the dynamic morphological changes of the Kosi and Ganga Rivers over a span of nearly four decades (1988–2024) using geospatial and remote sensing techniques. River systems are dynamic in nature, they bend and braid after flowing from higher elevations to low laying plains. They constantly alter their paths and dimensions due to natural processes and human interfering activities. Such rivers bring highly fertile alluvial sediments from top to bottom plains and spread along the floodplains, which helps in agriculture. While it also controls ground water levels which helps in reducing flood levels. But due to the formation of alluvial mega fans and constant flood events, embankments were made which control all its natural meandering patterns. While trying to solve a problem, high sediment deposit has caused many embankment failures resulting in devastating floods. This intervention has highly affected the socio-economic of people staying inside and outside of embankment. The objective of this study includes time-series mapping of the trajectory of both rivers which highlights significant transformations in patterns. And later study these parameters such as areas of sediment transfers, sinuosity, width, length, and channel migration patterns; at 8 years interval of timeline.

Data Acquisition from Landsat satellite images from 1988 to 2024. One image per year, (less cloud cover) preferred during post monsoon months. Image processing to extract river feature and generate centerlines of river to calculate length, sinuosity and other parameters. Key findings are, the amount of deposition gradually increases compare to erosions. Formation of small lakes, branching tributaries outside the embankment were observed. In 2008, as river flowed on an unusual path due to embankment failure resultant in high deposition on fields. Imbalance in sediment transfers cause shift in river trajectory. Both river shows stability in its areas after flood events. River Kosi exhibits higher braided patterns, which increased its length showing highly sinuous and unstable in nature due to sediment deposition. While the Ganga shows relatively stable yet progressive migration, few neck cut-off events and frequent meandering patterns explains changing length and gradually increasing sinuosity index, suggesting more controlled and less dynamic channel patterns. Future scopes are to predict the next pattern of river course, understand the sediment deposit and manage them, to improve disaster preparedness, land-use planning, having a sustainable river basin management.

WASH Innovations in Action: Modern Public Toilets as Catalysts for Inclusivity and Urban Comfort

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Access to safe and sufficient water, sanitation, and hygiene (WASH) facilities is critical for public health, especially in urban settings. However, many developing regions still face challenges in maintaining well-equipped and hygienic public sanitation systems. In Godawari Municipality, Nepal, while the region was declared Open Defecation Free (ODF) in 2018, the availability and maintenance of public toilets were still subpar. Despite the presence of 14 public toilets in Godawari, only nine were operational, with a majority of the facilities in poor condition both aesthetically and hygienically.

The Godawari Municipality's struggle to maintain these facilities pointed to a need for innovation in public toilet design and management. The existing systems were insufficient in terms of accessibility, cleanliness, and user comfort, which contributed to diminished quality of life. Public toilets should be more than just functional—they should serve as inclusive, comfortable, and hygienic spaces. The challenge was clear: WASH innovation at the public toilet infrastructure to meet the needs of a growing urban population and foster inclusive public health outcomes. The Integrated Urban Water Management (IUWM) project, led by ENPHO in collaboration with BORDA South Asia and Godawari Municipality, set out to address these challenges by renovating and upgrading the Chapagaun Public Toilet. The project focused on transforming the conventional Public Toilet into a model of WASH innovation by improving both its technology and service delivery, creating a modern and sustainable facility that could serve as a model for other municipalities in Nepal.

The primary objective of the Chapagaun Public Toilet renovation project was to integrate innovative WASH technologies and efficient service delivery models to create an inclusive and user-friendly facility that catered to the diverse needs of the community. The project aimed to elevate the Chapagaun toilet by improving accessibility, sanitation, hygiene, and comfort while incorporating sustainable management practices. The ultimate goal was to provide a replicable solution for other municipalities struggling with similar sanitation challenges. The Chapagaun Public Toilet, located in Ward 11 of Godawari Municipality, priorly constructed in 2013 was however functional but was neither user-friendly nor well-equipped to meet the community's needs. The toilet was not sufficiently maintained, and its management lacked the system to ensure long-term sustainability. To address these issues, an improvement plan was developed including physical, technological, human resource, financial, and management upgrades to elevate the Chapagaun Public Toilet to a modern standard. The refurbishment included several technological and infrastructural innovations, which were carefully integrated to ensure the facility met the basic needs services of the users. These innovations included; the installation of automated urinals, sensor-driven faucets, sensor-based flushing in the pans, automatic LED lighting , and automatic soap dispensers minimizing the need for physical interaction, and ensuring a more hygienic environment. Further, the provision of pad vending machines and sanitary disposal units for women ensured that the facility addressed the hygiene needs of all genders, fostering an inclusive environment. The project also integrated a community-driven governance and

business model for operation and maintenance. Caretakers were trained to manage the facility, and the inclusion of a coffee shop within the premises helped generate income, ensuring financial sustainability and efficient management of the toilet services.

The renovated Chapagaun Public Toilet now serves over 100 users daily and has become a model for public sanitation improvement in the region. It provides a clean, hygienic, and accessible space that meets the needs of a diverse urban population. The facility has received overwhelmingly positive feedback, especially from women who benefit from the installation of pad vending machines and sanitary disposal units. These additions have made it easier for women to maintain hygiene during menstruation, addressing a major gap in public sanitation services. The modernization of the Chapagaun toilet has also increased foot traffic, contributing to the sustainability of the facility. The integration of modern infrastructure, user-friendly services, and community-led management has created a sense of ownership and pride among local residents. Additionally, the income generated by the coffee shop has helped cover operational costs, ensuring the long-term financial sustainability of the facility. The success of the Chapagaun Public Toilet has sparked interest from neighboring municipalities, many of which are keen to replicate the model. The facility has become a point of interest for visitors and researchers, who view it as an exemplary demonstration of how public toilets can be transformed into inclusive, sustainable, and comfortable spaces. By integrating modern sanitation technologies, community involvement, and sustainable operational models, the project has successfully transformed a basic public toilet into a functional, comfortable, inclusive, and hygienic facility. This initiative contributes to several Sustainable Development Goals (SDGs), including SDG 6 on clean water and sanitation, by improving access to safe and well-maintained public toilets; SDG 11 on sustainable cities and communities, by enhancing public infrastructure for healthy urban living; SDG 5 on gender equality, through facilities designed to meet the hygiene needs of all genders, especially women. This project exemplifies the potential of WASH innovations not only in terms of technology but also in service delivery models. By addressing the needs of the community, incorporating sustainability features, and empowering local governance, the Chapagaun Public Toilet project serves as a replicable model for improving public sanitation in urban areas. It highlights the role of well-designed public toilets in transforming urban spaces into more inclusive, sustainable, and health-promoting environments.

Sustainable Management of Toilet

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In rural India, improper management of septic tank proximity to borewells poses serious public health risks, leading to groundwater contamination and waterborne diseases like diarrhea, typhoid, and hepatitis. This paper highlights the need for sustainable excreta management through a cluster-wise approach, including centralized collection centers, organic manure production, and community awareness. Emphasizing stricter regulations and infrastructure investment, it proposes measures to safeguard groundwater and promote sustainable sanitation practices. These efforts align with India's "Hamara Shauchalay: Hamara Samman" campaign, fostering improved health, dignity, and equality while advancing global sanitation and sustainability goals.

Maximising Capacity Utilisation in Waste Management Practices

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The research study, titled “Maximising Capacity Utilisation in Waste Management Practices”, focuses on Faecal Sludge and Septage Management (FSSM) in Odisha, India. With the significant increase in the adoption of onsite sanitation systems under the Swachh Bharat Mission in Odisha, there is a growing demand for effective FSSM in rural areas. The Urban-Rural Convergence approach addresses this need by utilising the existing FSSM infrastructure in urban areas to extend services to neighbouring rural areas, thus bridging the urban-rural divide. Following successful pilot programs in Dhenkanal and Angul, the Housing and Urban Development Department (H&UD), district administration, and municipal governments across the state are actively expanding this approach statewide. By eliminating the need for additional infrastructure and fostering institutional convergence, this approach optimises resource utilisation, mitigates environmental pollution, and reduces health risks associated with improper faecal waste management. However, it has been observed that the underutilisation of resources highlights specific challenges that need to be overcome to scale up operations in the Urban-Rural Convergence model successfully. The study involves quantitative and qualitative analysis of FSSM in six cities of Odisha (2 Municipal Corporations, 2 Municipalities & 2 Notified Area Councils) selected through purposive sampling method to develop strategies to maximise capacity utilisation of resources in waste management practices in Odisha involving policy recommendations. The research question and hypothesis aim to identify steps that can be taken to optimise capacity utilisation in waste management practices. The study seeks to understand the obstacles hindering optimisation in the existing FSSM ecosystem and provide recommendations to overcome these challenges. It specifically focuses on the Urban-Rural Convergence model and its potential to maximise capacity utilisation in Faecal Sludge Treatment Plants (FSTP). By examining the factors contributing to the underutilisation of FSTPs and developing a replicable and scalable framework, this study aims to identify solutions that can be implemented across all Urban Local Bodies (ULBs) in the state to develop a comprehensive FSSM action plan. Hence, the research focuses on identifying potential gaps and threats to the value chain in the Urban-Rural Convergence model and examined factors contributing to the underutilisation of the FSTPs. The role of technology in increasing the efficiency of resources involved in the value chain is also explored. This research was conducted using a formative research approach that involved focus group discussions (FGDs) and in-depth interviews (IDIs) with key stakeholders involved in the day-to-day operations of FSSM. These stakeholders included the city/deputy commissioner, executive officer, sanitation experts, plant operator, technical resource personnel, plant manager, and transportation department official who handles the procurement and contract of cesspool vehicles, among others. The study's methodology comprised five stages, starting with a literature review of secondary research on sanitation in urban India, the existing policy landscape, and the implications of various policies on sanitation in Odisha. The second stage involved the development of a framework to facilitate structured interviews and discussions based on benchmarking and analysis of best practices of FSSM across the country, highlighting the advantages and disadvantages of various FSSM business models. The third stage involved site visits to gather

information under categories such as operating models, access and storage, emptying and transportation, and treatment and resource recovery based on the developed framework. In the fourth stage, data analysis was performed based on the site visits' findings to identify issues in the existing ecosystem. Finally, recommendations were made for the identified issues in the fifth stage, and an action plan was developed for their implementation. The research revealed that most of the FSTPs in the cities of Odisha are utilised less than 55% of their actual operational capacity. Overall, this study's comprehensive and systematic approach provides valuable insights into the FSSM practices in the identified cities and lays the groundwork for future research and implementation of effective waste management strategies. It also identified reasons for underutilisations which were caused due to multiple factors, including a lack of awareness among households in the Gram Panchayats (GPs) in the state, a lack of transparency and accountability on Desludging Service Operators involved in operations in both urban and rural areas, and an absence of ULB-specific bylaws for FSSM. Additionally, this research explores how existing structures, such as social capital and social networks, can be leveraged to mobilise sensitisation programs inventorying septic tanks that would increase capacity utilisation. The initiatives proposed could be scaled across all the 115 ULBs and their tagged GPs within the state. Despite its limitations, such as the reliance on FGDs and IDIs, the research concludes that the framework developed can be replicable and scalable as it identifies parameters hindering optimisation in the existing FSSM ecosystem and provides actionable solutions that can be implemented across all ULBs in the state. The policy recommendations offer a pathway for the capacity maximisation of FSTPs in ULBs, facilitating safe waste management practices and enabling the development of a comprehensive FSSM action plan. These findings inform the design of targeted interventions and policy frameworks to address underutilisation issues, guide the replication of best practices, and ensure sustainable sanitation management across the state. Additionally, implementing an active monitoring regime to track the utilisation of FSTPs can significantly improve public health outcomes, reduce environmental contamination, and enhance the efficient use of resources, thereby contributing to the overall improvement of waste management practices and sanitation standards in the identified cities and further to other urban and rural contexts.

From Tanks to Treatment: Private Sector Redefining Sanitation Services

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The involvement of private sectors in various fields has demonstrated more effective outcomes. Butwal Sanitary Pvt Ltd., a company engaged in desludging services and operating a private faecal sludge treatment plant, serves as a notable example of a private sector entity overcoming challenges in faecal sludge management and fostering opportunities for implementing sustainable sanitation. Butwal Sub-metropolitan City stands as one of the oldest municipalities in Nepal and serves as an economic hub in Lumbini Province, West Nepal. With approximately 40,876 households and a population of 195,054 residents, the city is undergoing rapid growth and urbanization. Despite this, the establishment of proper sewerage infrastructures remains a pending need, as 80.4% of households rely on onsite sanitation systems that necessitate regular septic tank emptying and appropriate disposal. While the sub-metropolitan has been actively providing sanitation services, particularly focusing on solid waste management, it grapples with several sanitation challenges. The city currently lacks a proper desludging system, and there is no designated space for the disposal and treatment of sludge.

Realizing the potential in faecal sludge management, seven distinct private desludging companies collaborated to establish Butwal Sanitary Pvt Ltd. This entity not only delivers desludging services but has also developed its own Faecal Sludge Treatment Plant (FSTP) to ensure the proper handling of collected faecal sludge. The enterprise has flourished and has future aspirations to produce organic fertilizers by repurposing the faecal sludge, completing the cycle within the sanitation service chain. Up until 2022, numerous desludging service providers operated in the city and its surrounding areas without a proper desludging mechanism, resulting in varying service charges. Notably, the collected faecal sludge was indiscriminately disposed of in the vicinity of the forest and the adjacent river, with a royalty payment of Rs 5000 for each disposal trip.

However, in 2022, the community forest prohibited any further disposal, posing a significant challenge for desludgers as they lacked an alternative space for sludge disposal. In response, seven de-sludging service providers collaborated and held a series of discussions. They also sought support from the sub-metropolitan for disposal solutions. Nevertheless, the sub-metropolitan committed to aiding only if the service providers could secure an area for proper disposal.When the desludgers encountered a lack of support from the local authorities, they took matters into their own hands and established the company "Butwal Sanitary Private Limited." To address the land issue, they actively sought suitable land space, engaging in discussions with various community forest groups. Eventually, they secured a lease for land in Butwal-10, Ramanagar Community Forest, marking the initiation of their desludging operations as a new venture.The current Faecal Sludge Treatment Plant (FSTP) is the result of a series of upgrades. Initially, the venture commenced with a few drying beds, followed by the addition of a thickening tank and more sludge drying beds. Subsequently, a dewatering machine was incorporated to extract organic fertilizer. Presently, the system has the capacity to treat 12,000 liters of faecal sludge and produce 800 kg of organic fertilizer.Beyond technological advancements, the company streamlined its operations by establishing an office in

Butwal sub-metropolitan city ward no 10. Administrative processes are managed through a call center, handling requests for desludging services made via phone calls. The efficient planning of desludging trips optimizes the use of tanks and human resources. The entire process, from desludging to treatment at the plant, is meticulously handled by the operating team, with comprehensive records maintained.The uniqueness of this business venture lies in the combination of providing desludging services along with taking the additional step of investing in and managing a dedicated FSTP, thereby committing to not only offer a service but also to responsibly handle the waste generated through that service, contributing to more sustainable and environmentally friendly sanitation in practices.

Challenges - 1. Butwal Sanitary Pvt Ltd faces a hurdle in scaling its business due to a lack of investment in marketing initiatives. This may impede the overall growth of the company by limiting the acquisition of new clients and the expansion of its customer base, 2. The company grapples with the challenge of insufficient technological knowledge, which is why a huge amount of investment has been made so far in trying out different technologies. Keeping abreast of technological advancements is crucial in the sanitation sector to enhance operational efficiency, optimize resource utilization, and stay competitive, and 3. The absence of support from the local government presents a significant challenge.

Learnings - 1. In addition to providing desludging services and managing disposal, Butwal Sanitary Pvt Ltd showcases itself as a waste recovery center by transforming collected sludge into organic fertilizers, 2. Different individual sanitation service providers coming together for their collective provision of desludging services highlight the feasibility of private sector involvement in the sanitation business, 3. The company investing solely in business without any support from foreign investment or local government, has convincingly set a good example and well demonstrated the feasibility of sanitation business even for the private sector, 4. While sanitation services are often perceived as the responsibility of local bodies, collaborating with the private sector and creating an enabling environment can significantly enhance sanitation services and status, potentially avoiding the need for new investments by local governments, and 5. Engaging the private sector in the sanitation sector opens up opportunities for collaboration with local government bodies and hence the local government may avoid having to make new investments. From managing faecal sludge to producing organic fertilizers, the company has evolved into a waste recovery hub, operating sustainably without external aid. It exemplifies the viability of private-sector sanitation ventures, highlighting the need for local governments to foster private sector engagement for sustainable sanitation solutions

Towards Citywide Inclusive Sanitation: Engineering design and testing of a novel faecal sludge treatment facility for South Africa – A Case Study approach

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There is no universal solution to urban sanitation challenges. It is essential to develop locally relevant and innovative solutions along the sanitation service chain. Citywide Inclusive Sanitation (CWIS) is a public service delivery approach to planning and implementing urban sanitation systems to achieve outcomes summarised by Sustainable Development Goal 6: safe, equitable, and sustainable sanitation for everyone in an urban area. The South African government is committed to ensure that everyone has access to safely managed sanitation in line with the Sustainable Development Goal (SDG) 6.2 target. Sanitation services are provided through a mix of sanitation systems which include centralised and decentralised wastewater treatment systems (offsite), and non-sewered (onsite). To ensure sustainability of the environment transitioning to a circular economy within the South African water sector is required, which is in line with the Sustainable Development Goals. Circular Economy, in the context of sanitation, focuses on the whole sanitation chain. In order to realise the full potential of the CWIS, implementing a circular sanitation economy approach which is embodied in CWIS principles.

Research question: How can the citywide inclusive sanitation and circular economy approaches be applied to manage faecal and wastewater sludge in South Africa to improve sanitation service delivery?. Aim: Design a novel faecal sludge treatment facility for South Africa, using lessons learned from Lusaka, Zambia and using a commercial sanitation business in South Africa, to explore resource recovery and circular economy applications.

Objectives - 1. Produce updated basic and/or intermediate Sludge Flow Diagrams (SFDs) and City Service Delivery Assessments (CSDA) for eThekwini Municipality, 2. Quantify and characterise the incoming waste streams at an FSTP in Lusaka, Zambia, 3. Quantify and characterise the quality of sludge produced by a commercialized and innovative on-site sanitation system in South Africa, and assess the suitability of a FSTP or other treatment technologies for its management, 4. Produce technical engineering designs/ renderings of a faecal sludge treatment plant (FSTP), with co-composting/co-treatment options for South Africa, with eThekwini Municipality as a case study area, 5. Perform a techno-economic analysis of the feasibility of the facility when combined with other faecal sludge treatment options, whilst identifying the synergies between greenhouse gas emissions/climate change and water, energy and food (WEF) nexus that may impact sustainability of the FSTP in South Africa, and 6. Develop a novel policy brief, for improved sanitation service delivery in a city.

The following preliminary results (linked to the objectives) have been found:- 1. The latest (2016) SFD for eThekwini Municipality shows that 74% of excreta is managed safely with 48% coming from waterborne toilets on the central sewer network. The bulk of the excreta that is not safely managed is from the 17% of households that do not have improved toilet facilities or access to an emptying service (making up 16% unimproved, community-built pits that are not emptied or buried and 1% open defecation) as well as the estimated overflow from blocked sewer lines. Comparison of the integrated desk-based assessment for an SFD and CSDA will be done on the Feacal Sludge

Management Alliance Toolbox site, 2. BORDA Zambia has not prioritised quantifying the character of the waste coming into their FSTP, thus, this study will be the first to do so. However, it should be noted that the FSTPs treat waste streams from septic tanks (over 85% moisture content) and dry pit toilets (which need some moisture added). This sampling campaign will be carried out in 2025, 3. Preliminary results for the faecal sludge container-based on-site sanitation system, and the polymer film used to contain the waste were tested to determine treatment and potential reuse. Physical, chemical, mechanical, thermal and microbiological parameters were tested on both. Preliminary results show that the sludge has properties that are consistent with waste streams that can be treated in DEWATS FSTP, LaDePa, etc. (especially in terms of moisture content). Burying on site is not possible, unless dried before. The polymer film, in its current state, is considered hazardous (medical) waste and disposed as such. The quantities collected at the moment (in terms of mass) are negligible for any commercial reuse, 4.Production of technical engineering designs/ renderings of a faecal sludge treatment plant (FSTP), with co-composting/co-treatment options for South Africa, with eThekwini Municipality as a case study area will be done using the BORDA Excel Tool for decentralised treatment design. For the sake of GSAC 2025, a generic design (process and structural) and render can be produced, as this study is running until 2026/2027 and not enough data has been collected as yet, 5.Perform a techno-economic analysis of the feasibility of the facility when combined with other faecal sludge treatment options, whilst identifying the synergies between greenhouse gas emissions/climate change and water, energy and food (WEF) nexus that may impact sustainability of the FSTP in South Africa. For the sake of GSAC 2025, the methodology of how this will be done, will be presented, in the hopes of gathering needed input from other global south experts, and 6.Developing a novel policy brief, for improved sanitation service delivery in the city of eThekwini, will be done once all data has been collected and quantified.

As the study is still in progress in the beginning stages, preliminary data will be presented, and the progress of the project and way forward will be discussed. With the hopes that input from other experts in the field, will dictate the way forward, should any gaps and opportunities be identified. The results will add the body of literature in the field of citywide inclusive sanitation, particularly in South Africa where it is lacking. A much needed technical brief, along with the policy brief, will be published for the whole study. As well as identifying the synergies between climate change, water, energy and food that may impact sustainability.

Feasibility for Omniprocessor establishment in Muttathara Sewage Treatment Plant for sludge management, Thiruvananthapuram, Kerala

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Thiruvananthapuram, the capital of Kerala and only city with extensive sewer connections in the state. The wastewater from the residential units and commercial establishments reaches the 107 MLD sewage treatment plant at Muttathara. Faecal sludge from houses are collected and delivered by the corporation licensed trucks and 90 to 100 trucks deliver the faecal sludge to the STP daily, who are monitored through the online platform managed by the Corporation. The units of Activated Sludge Process based STP comprises of Screen chambers, Grit chambers, Aeration tanks, Secondary clarifiers, Sludge Thickeners, Sludge Drying beds, Chlorination units and Centrifuge mechanism. STP treats nearly 55-65 MLD of sewage daily, which includes the faecal sludge received for co-treatment. The STP is faced with long standing sludge management issues for more than 10 years sludge generated through the STP process is dumped in the STP premises leading to land loss in the area. There is no demand for treated water and sludge, which is the primary reason for sludge accumulation and dumping in the STP premises.

Omni processor is a decentralised waste treatment system that kills pathogens while recovering valuable resources from faecal sludge, biosolids, and other waste streams to generate electricity for its operation and generate treated water, distilled water and ash as the by-products. Omniprocessor was proposed as a solution to solve the existing sludge management issues in the STP. This study assessed the technical feasibility for Omniprocessor implementation to treat the secondary sludge of the STP. The calorific value of the secondary sludge was primarily assessed through composite sampling for four days and the test results revealed the calorific value was in the range of 7 MJ/kg to 12 MJ/kg. This calorific value range is found to be feasible for implementing the Omniprocessor with adjustment of calorific value in case of drop in the calorific value of the incoming sludge through co-firing of biomass. Currently, the demand for the treated water and ash is not big in Trivandrum but the same can be expanded by taking regulatory measures. The proposed solution not only resolves the longstanding sludge management issue of the STP but also recovers land lost to sludge accumulation, closing the loop in the city's sanitation service chain.

NBS for Waterbody Rejuvenation of Pavi Sadakpur Pond, Loni, Ghaziabad, Uttar Pradesh

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The Pavi Sadakpur Water Body Rejuvenation Project, undertaken by Jalchakra Innovations LLP, stands as a testament to sustainable ecological restoration through Nature-Based Solutions (NbS). Located in Loni, Ghaziabad, the water body was severely polluted, with more than 30% of its surface area covered in various types of organic and inorganic floating waste, including animal carcasses, blood and waste from butcheries, chemicals, and dyes, among others. The adjoining villages discharge approximately 7 to 10 million liters per day (MLD) of untreated sewage into the pond, leading to highly degraded water quality, significant greenhouse gas emissions, and an environment conducive to waterborne and vector-borne diseases. The pond also served as a major breeding ground for mosquitoes and other pathogens.

Initiated in March 2024, the project was executed using Cownomics® Technology, a proprietary NbS for restoring soil, water, and air to their native, healthy, and uncontaminated states. This approach achieves zero discharge and a zero carbon footprint without relying on mechanical, chemical, or biological interventions. This technology is done IN-SITU without the necessity for any plant or machinery. The project is being monitored by IIT Delhi, which has been conducting an Environmental Impact Assessment (EIA) since the project's inception. The treatment is structured into three distinct phases: Phase 1: The Resurrection Phase: This initial phase, lasting three months, focused on reviving the native microbiota of the water body. During this period, foul odors and mosquito populations were eradicated. Notable improvements included substantial reductions in Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Chemical Oxygen Demand (COD) values. The water's viscosity decreased, its color became lighter, and transparency increased. Additionally, the previously stagnant water began exhibiting continuous wave patterns. Phase 2: The Restoration Phase

Spanning another three months, this phase aimed to re-establish soil capillaries linked to the aquifer by ecologically consuming (eradicating) the deposited sludge, a process termed "eco-dredging" (patent applied). As a result, the water body's holding capacity improved significantly due to the sludge's ecological consumption. Phase 3: The Rejuvenation Phase (Yet to happen)

This six-month phase calibrates the metabolic rate of the water body to digest daily incoming loads of pollution and contamination. The digestion capacity shall be fine-tuned to handle new contamination on a daily basis. Upon completion of this phase, marking one full year of treatment, the water body shall be restored to its native state.

The air quality in the vicinity has also improved remarkably due to the nullification of greenhouse gases and a reduction in particulate matter. The revitalized water body contributed to enhanced soil health and has became a Neuro-Immuno Booster, benefiting agriculture and other water-centric activities in the area. This dual improvement in air and soil quality highlighted the comprehensive benefits of the rejuvenation process, extending beyond the

immediate water body. There is complete revival of flora and fauna due to the biodiversity gains and the waterbody is thronged by various species of birds and animals in and around the waterbody. A defining feature of this project was its community-centric approach. Local residents were actively involved in cleanup efforts, fostering a sense of ownership and raising awareness about sustainable water management practices. The rejuvenated water body has become a valuable resource for the community, enhancing living conditions and morale. The Pavi Sadakpur Water Body Rejuvenation Project serves as a scalable and replicable model for addressing similar challenges across India. By leveraging advanced, nature-based solutions, the project not only restored a critical natural resource but also contributed to broader goals of environmental conservation, community well-being, and sustainable development.

AquaWISE: A Decision Support Tool for Greywater Treatment Solutions in Government Schools in Semi-Arid India

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Government schools in the arid and semi-arid regions of the Deccan plateau in India face severe water security challenges. These schools struggle with inadequate water supply, lack of wastewater management systems, and poor sanitation infrastructure. Such conditions pose significant health risks to children, particularly to girls, who are disproportionately affected by unhygienic school environments. Greywater—wastewater generated from kitchens, bathrooms, and cleaning activities—represents an underutilized resource with the potential for reuse, which could alleviate both water scarcity and environmental health risks. However, the absence of systematic wastewater treatment in these schools exacerbates water insecurity and compromises health standards. The majority of government schools in these regions have limited resources and operate with minimal budgets compared to their private counterparts. This resource disparity, coupled with a lack of designed wastewater management systems, contributes to unhygienic conditions that can adversely affect children's health and well-being. Despite the growing recognition of greywater as a reusable resource, its treatment remains an underexplored area in the context of school sanitation. One of the primary challenges of implementing a school-specific treatment system is that the baseline data on water and wastewater quality at the school level are expensive and scarce. This especially applies to the global south, resulting in treatment systems that are either over-designed or under-designed. Such inefficiencies lead to suboptimal treatment outcomes and misallocation of resources. Addressing these gaps requires innovative, evidence-based, and cost-effective solutions that account for the unique socio-environmental challenges faced by schools in semi-arid regions.

In response to these challenges, ATREE (Ashoka Trust for Research in Ecology and the Environment) developed AquaWISE, a decision support tool designed to optimize Nature-based Solutions (NbS) for greywater treatment in schools. The tool minimizes the need for costly baseline data collection and allows users to generate school-specific wastewater treatment solutions tailored to local conditions. The core objective of this research was to develop AquaWISE, a webtool that offers a user-friendly interface that requires minimal inputs from practitioners and policymakers. Using a mixed-methods approach in collecting water quality and socio-economic data, the development of AquaWISE was informed by a detailed survey of 23 government schools located in urban, peri-urban, and rural areas around Bengaluru, India. Key data inputs included information on the student and adult populations in each school, details on water supply sources (public or private) and the quantity of water available, insights into existing greywater disposal methods, data on food preparation practices, the presence of operational kitchens, the availability of vacant land within school compounds, water quality testing, and the classification of schools based on their location (urban, rural, or peri-urban). This comprehensive dataset was instrumental in designing the backend algorithm of AquaWISE, which enables users to input minimal yet critical information to receive tailored treatment solutions.

By reducing the need for extensive baseline data collection, AquaWISE offers a cost-effective solution for implementing wastewater treatment systems in resource-constrained schools. The tool provides location- and context-specific treatment recommendations, ensuring optimal design and resource allocation. Furthermore, AquaWISE has the potential to be adapted for use in diverse geographic settings, including mountainous and well-drained alluvial regions. Its intuitive interface empowers school administrators, policymakers, and practitioners to make informed decisions about wastewater treatment and reuse. By enabling the reuse of greywater, AquaWISE addresses critical water security issues while promoting sustainable water management practices in schools. Treated greywater can be repurposed for non-potable applications such as flushing toilets and irrigation, reducing dependence on freshwater sources. This approach not only improves the overall hygiene and sanitation standards in schools but also contributes to environmental sustainability by mitigating the risks associated with untreated wastewater disposal. Users need to provide basic information such as the school's location (urban, rural, or peri-urban), the type of school (lower primary, higher primary, or high school), sources of water supply (public or private), the number of children and adults in the school, whether the school has an operational kitchen, the availability of vacant land within the school compound, and the intended use of treated greywater (e.g., reuse for flushing or irrigation, or treat-and-release). Based on this input, AquaWISE generates tailored recommendations for greywater treatment solutions, including capital expenditure (CAPEX) estimates and space requirements. The tool's algorithm accounts for the specific end-use of treated water, recognizing that water quality requirements vary depending on the intended application. For example, schools planning to reuse treated water for flushing must achieve low organic matter levels (<10 mg/l) and pathogen-free conditions (as indicated by residual chlorine levels), which in fluence both costs and design specifications.

While AquaWISE represents a significant step forward in addressing water and wastewater challenges in schools, its implementation is not without challenges. The tool's current focus on semi-arid regions limits its immediate applicability in other climatic and geographic contexts. Future research should explore the feasibility of extending AquaWISE's applicability to diverse regions, including mountainous areas where steep terrain poses unique challenges for water management, alluvial regions characterized by high water tables and well-drained soils, and coastal zones where saline intrusion and water quality issues are prevalent. Expanding the tool's scope to include other regions will require further data collection and algorithm refinement to accommodate varying wastewater characteristics and treatment requirements. AquaWISE is a pioneering decision support tool that leverages interdisciplinary research to address critical water and sanitation challenges in government schools of semi-arid India. By providing tailored, evidence-based solutions for greywater treatment, the tool empowers schools to improve hygiene and sanitation standards, reduce health risks, and promote sustainable water management practices. With its potential for scalability and adaptability, AquaWISE represents a valuable contribution to the global effort to achieve water security and environmental sustainability in educational institutions.

Desludging fee Calculator for the State of Uttarakhand

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The sanitation vertical of NIUA is driving the Uttarakhand state government to mainstreaming FSSM and IWSM through supporting in operationalizing the State Septage Management Protocol across all the Urban Local Bodies (ULBs) in Uttarakhand. The septage byelaws, formulated in adherence to the State FSSM policy, mandated the registration of all private players supporting desludging services within the administrative boundary. These byelaws also standardized user charges for different categories based on building type. Despite these measures, the issue of equity continues to surface, highlighting the need for a balanced approach that benefits both users and desludging operators. A significant challenge is that not all private desludging operators adhere to the prices mandated by Urban Local Bodies (ULBs). The demanding nature and scope of work, coupled with the limited competition among desludging operators, often results in users being subjected to exorbitant desludging charges. In many cases, even the charges set by ULBs are not scientifically justified. The resulting byelaws, unfortunately, took a one-size-fits-all approach, applying a uniform rationale across ULBs with varied terrains and haulage distances. This approach widened the gap for users, leaving them with limited choices: opt for demand-based desludging from a registered operator, seek cheaper alternatives within the vicinity, or build larger tanks that remain unemptied for years.

For most individuals, the pursuit of cheaper alternatives takes precedence. However, this often comes with serious consequences. Many of these unregistered operators resort to illegal dumping of emptied septage into nearby water bodies or vacant land. Such practices pose a significant threat to public health and environmental safety, undermining the Open Defecation Free (ODF) status achieved under the Swachh Bharat Mission 1.0. The need for a more context-specific, equitable, and scientifically grounded desludging fee structure is imperative to address these challenges, ensuring affordability for users while maintaining compliance among desludging operators. Considering the hilly region, where the context for ULB changes within a few kilometers, and with major sources of freshwater rivers, safely emptying and transferring septage for treatment faces a significant challenge due to the user charges levied by the ULBs. For the past six years, the National Institute of Urban Affairs (NIUA) has worked closely with the Urban Development Directorate of Uttarakhand to formalize the state's FSSM protocol for septage management, culminating in its establishment in 2017.

This initiative has had a notable impact, with 71 out of 105 ULBs gazette-notifying their septage byelaws. While these byelaws have rationalized desludging user charges, the challenge of demand-based desludging persists. Residents often resist paying the prescribed user charges, opting instead for cheaper, informal alternatives. The user charges range from INR 2,000 in the plains, including cities like Dehradun, Rishikesh, and Rudrapur, to as much as INR 15,000 in hilly areas like Uttarkashi, where desludging vehicles must be called from nearby ULBs through mutual consent, adding irregular haulage charges to the service cost. To establish a more scientific rationale for user charges in the hilly context and to promote transparency, NIUA began developing a desludging fee

calculator in 2022, this initiative was informed by cross-learning from multiple stakeholders and sector experts in the sanitation domain. The goal was to address irregularities in demand-based pricing and escalating service costs. The resulting tool calculates desludging fees using existing data on faecal sludge and septage management (FSSM) collected by ULBs. It considers critical factors such as haulage distance, terrain, and freight weight, ensuring a fair and transparent pricing structure. Pilot ULBs were selected to validate the fees calculated by the tool as the tool's introduction aims to standardize user charges, thereby encouraging residents to use municipal desludging services instead of cheaper, informal alternatives. This shift is expected to reduce illegal dumping, which poses significant risks to public health and the environment. Illegal dumping of septage often leads to contamination of nearby water bodies or vacant land, undermining the Open Defecation Free (ODF) status. In the long run, the desludging fee calculator aims to support ULBs still developing their septage byelaws by providing a clear rationale for desludging charges. At a national level, where such regulations are not yet established, the tool could be integrated as part of the National Urban Digital Mission (NUDM). This would offer residents clear and precise fee calculations, promoting accountability and transparency in desludging services across India.

Modeling the Impact of the 2024 Flood Event in Vadodara

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Organization: CEPT University | India

Floods are among the most frequent and destructive natural disasters worldwide, causing significant economic losses and affecting millions of lives annually. Globally, flood events are increasing due to climate change, with low-lying urban areas particularly vulnerable. In India, nearly 15% of the land is prone to flooding, resulting in recurring damage to infrastructure, livelihoods, and human life. Vadodara, situated along the Vishwamitri River, is no exception to these challenges. The city faces heightened flood risks due to rapid urbanization, changing land use patterns, and the effects of climate change. The August 2024 flood, during which the Vishwamitri River surpassed its danger level by 2.7 meters at Kalaghoda, exemplifies the growing severity of these events. This flood broke a 19-year record and caused widespread inundation, exceeding even the extent of the devastating 2005 floods. These conditions highlight the urgent need for precise flood risk assessment and management in Vadodara.

A 2D HEC-RAS model combined with GIS was used to carry out this analysis of estimating the influence area of floods. The 2D HEC-RAS model was chosen for its ability to simulate complex flood dynamics in urban areas accurately. Using the diffusion wave equation—a simplified form of the St. Venant equations that neglects inertial effects—this model effectively simulates flow across the floodplains. Additionally, the Muskingum method was employed within HEC-HMS to model stream flow, focusing on prism and wedge storage to capture changes in channel storage during flood waves. Land Use/Land Cover (LULC) data, essential for estimating the area's permeability, was sourced from the Sentinel platform at a resolution of 10 meters. The data showed that 81.21% of the Vadodara city's area is built-up and impervious. A 10-meter resolution Digital Elevation Model (DEM) from the Bhuvan platform represented Vadodara's topography, with an average elevation of 35.5m, a lowest elevation of 12m, and a highest elevation of 58m. Rainfall data from the August 2024 flood event and water level data from the Kala Ghoda station in Vadodara were provided by the Vadodara Municipal Corporation (VMC). This comprehensive dataset enabled the development of a robust flood model, simulating how floodwaters would spread across the city under varying conditions.

The flood hazard map (depth map) generated from the HEC-RAS model was overlaid with demographic data in GIS to calculate exposure across six different flood depth levels for each ward. The analysis revealed that, at the ward level, Ward 12 has the highest exposure to flood events, with 99.7% of its population exposed, mainly due to its lower elevation, which leads to greater flood extent and depth. At the city level, Ward 9, with the largest population, has 10.266% of its residents exposed to the flood event, making it the ward with the highest number of people at risk. In contrast, Ward 12 has the highest percentage of its area exposed to flooding, covering 18.78% of its total area. The results emphasize the need for city planners and policymakers to focus on wards with high population exposure for immediate flood mitigation while also considering wards with a significant percentage of their area exposed, which will help identify high-risk zones for future development.

These findings underscore the influence of land use, population density, and topographical characteristics on flood exposure in Vadodara. By highlighting areas at significant risk, the study provides a foundation for developing targeted flood management strategies, such as enhancing drainage infrastructure, restricting development in flood-prone zones, and establishing effective early warning systems. Such interventions will be essential for reducing the impact of future flooding events and enhancing Vadodara's resilience.

In conclusion, this study exemplifies the value of integrating 2D HEC-RAS modeling and GIS for flood risk assessment. These advanced tools offer a precise and detailed picture of flood hazards and exposure, which is especially critical as climate change challenges urban areas with more extreme weather events. By adopting data-driven strategies and investing in flood resilience, Vadodara can work toward a safer and more sustainable future for its citizens.

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CWAS began its work in 2009 with a focus on improving water and sanitation services in India. Its activities include policy support, action research, advocacy and capacity building. The CWAS team works closely with city and state governments, enabling them to improve service delivery.

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