BRIDGING THE WASTEWATER TREATMENT GAP IN RURAL INDIA: A DECENTRALIZED CIRCULAR ECONOMY SOLUTION

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Abstract

India is facing major challenges with sewage and wastewater management. Around 62 billion liters are generated, of which only 37% go under treatment. In Haryana villages, this issue is critical, as on one side their people are facing water scarcity as 60% of farmlands depend on rainfall. This paper presents a Hari Pravah model i.e., a decentralized and cost-effective approach for wastewater treatment focusing on resource recovery and circular economy fundamentals. The Hari pravah, planned for Banchari a Haryana Village, based on a hybrid sewage treatment plant with primary, secondary and tertiary treatment reaching 100% waste utilization. This model generates three revenue streams i.e. treated water for irrigation, organic fertilizers and biogas for energy. This strategy helps in increasing crop yields by 15-20%, and reduces CO_2 emissions by 2.7 tons per ton of biomethane. It also generates job and entrepreneurial opportunities for villagers, encouraging rural development and resource recovery. The Hari Pravah model provides an expandable and sustainable method for wastewater management in growing economies, highlighting the importance of decentralized and resource directed methods.

Keywords: *Resource Recovery, Biomethane, Wastewater Management, Sustainable Agriculture, Rural Development and Circular Economy*.

Introduction

The National level Crisis:

India is dealing with a bigger challenge in sewage and wastewater management. According to 2025 data, India generates 62 billion litres of sewage per day, of which only 28 to 37% undergoes treatment (CPCB, 2021; CPCB, 2022). The remaining sewage is released into open land, shallow groundwater, and water bodies such as ponds, johads, and rivers like the Yamuna.This untreated water causes serious damage to soil and water by contaminating river biodiversity and the population living near these discharge places and water bodies. According to NITI Aayog, from an economic point of view, this inefficiency of wastewater management leads to a loss of ₹ 3.5 Lakh Crore due to healthcare costs, environmental degradation, and reduced productivity (NITI Aayog, 2019). The figures show that there is a gap between sewage generation and its management with the help of sustainable actions, mainly outside urban centers.

The regional focus on Groundwater Emergency in Haryana:

In an overall understanding, Haryana is identified as a "red zone" for water security in India due to historically unsustainable practices of intensive cropping like rice and wheat over decades that has exhausted groundwater resources (CGWB 2023).

There has been an extreme decline in the water table after decades of crop production, with measurements ranging between 30 - 200 feet (CGWB 2022) within a decade, primarily in the southern and central blocks of Haryana as a result. Falling water tables are both an ecological and large economic burden to farmers. Water levels that have fallen as a result of overuse require increasing amounts of electricity and diesel; take longer to irrigate due to a decreasing ability to use pumps; and more frequent pump failures as farmers attempt to access groundwater supplies. Additionally, as the fresh aquifers become depleted, farmers are forced to pump water for crops from deeper saline layers, which will ultimately degrade soil quality and yield. Due to unpredictable rainfall, high input costs for agriculture (plastic/chemical fertilizers) to deal with declining soil quality, and reduced groundwater supply create a vicious cycle of debt for small and marginal farmers.

The Nexus between Chemical and Health

Another major issue in rural Haryana is over dependency on chemical fertilizers such as urea and DAP (Di-ammonium Phosphate) for farming which is also closely linked to water stress. The use of chemical fertilizers in farming has increased the crop yield but farmers have constantly reported about declining soil health, microbial diversity in the soil and nutritional quality of food grains (FAO, 2015; Pingali, 2012). Recent studies in the medical field have indicated a link between the excessive use of chemicals in farming and increasing cases of wheat and gluten allergies in the region (Makharia et al., 2011; Gupta et al., 2020). Extensive use of chemical fertilizers has led to the degradation of soil microbial health, which has directly shown an impact on the protein structure of crops such as wheat (Singh, 2018; FAO, 2015). Farmers in Banchari village explained these changes by stating that while earlier crops had more “jaan” (i.e., life and nutritional value) but less yield, today's crops have more quantity but very little nutritional value which leads to a rise in health issues even in families that eat their own homegrown produce. This raises questions on the long-term food safety and soil sustainability (Field Observations, 2026).

The circular economy as a management strategy:

In India, sewage and wastewater have always been thought of as waste, not an opportunity. Traditional management practices are based on a linear approach. They collect, treat (but only partially) and then dispose of sewage. This linear approach did not contribute towards solving the many interrelated issues such as water scarcity, soil degradation, and rural livelihoods. This research has approached sewage and wastewater from a circular economy perspective, treating sewage as a valuable bioproduct and not as waste. It has also identified the opportunity to solve the issues of sanitation and water scarcity at the same time by taking a decentralized approach to treatment for the recovery of resources (UN-Water, 2017; Andersson et al., 2016). The Hari Pravah model is examined as a case study of this transition by analyzing how a hybrid Sewage Treatment Plant (STP) can convert into a triple revenue stream at the village level.

- Reusing treated sewage water for irrigation purposes helps in reducing dependence on groundwater.
- Using produced biogas for energy needs in households and small industries.
- Using produced organic fertilizers (Orgatlizer) in farming can increase soil fertility and decrease the use of chemical fertilizers.

This study examines how grassroots innovation can provide a scalable roadmap for sustainable global management practices through this integration.

Table 1
Centralized vs decentralized wastewater management system

Feature	Centralized Wastewater Management System	Decentralized Wastewater Management System (Hari Pravah Model)
System Framework	It is based on large scale STPs covering wide geographical areas and are primarily designed for high density urban areas.	It consists of a small-scale village level treatment framework integrated within the local ecosystem. It is designed specifically for rural settlement.
Infrastructure Needs	For transporting wastewater to a single treatment location, a larger underground sewer is required.	It requires very minimal piping infrastructure since treatment occurs very close to the actual source of wastewater generation.
Capital Expenditure	It requires huge capital expenses for sewer connectivity, land acquisition, and large mechanical installations, which makes it economically impractical for villages like Banchari.	It requires lower capital investment as it depends on localized treatment units and has less dependence on the requirement of large-scale civil infrastructure.
Operational Dependability	It is highly sensitive to power outages and voltage fluctuations, i.e., very common in villages. This will lead to system failure and partial treatment.	It will remain functional even during power outages and it will ensure consistent treatment in village settings.
Maintenance Requirements	It will require specialized engineers, imported spare parts, and high recurring maintenance costs.	While it can be easily operated by locally trained youth having basic technical skills, that will reduce long term costs.
Resource Recovery	In this, treated water and sludge are located far from agricultural land, making reuse logistically difficult and costly.	It enables immediate reuse of treated water and "Orgatlizer" within the village by eliminating transport and handling costs.
Environmental Approach	It follows a linear "collect, treat and dispose" model with limited attention to reuse and recovery.	While it operates on a circular "recover and reuse" model converting waste into valuable resources.
Suitability for Village sustainability	It is often ineffective in villages due to technical, financial, and institutional limitations.	It is technologically appropriate, economically viable, and socially acceptable for rural sustainability.

Source: Gutterer et al., (2009), Massoud et al. (2009), CPCB (2023)

Scope of Analysis Considerations and Regional Overview

Socioeconomic status of Banchari village

Banchari Village of Palwal District located in Haryana State, India. According to a recent census, there are 13,300 residents living in 2,000 households in the village (Census of India, 2011; District Administration Palwal, 2024).

The economy of Banchari is majorly agrarian. Out of the total geographical area of 1840 hectares, around 1556 hectares are used for farming activities (Census of India, 2011; Department of Land Records, Haryana, 2023). A major part of the population, around 1,429 residents, is dependent on agriculture either as labourers or as cultivators. In recent times, Banchari has been undergoing a shift toward industrialization due to its location near NH-19 (National Highway-19) and the KMP Expressway (NCR Planning Board, 2021; Town and Country Planning Department, Haryana, 2023).

Farming cycle & watering methods

The farming cycle of Banchari village is common as used in South Haryana. The main crops produced there are wheat, cotton, mustard, and bajra (Department of Agriculture & Farmers Welfare, Haryana, 2022). A limited number of other crops are produced, including jowar, sugarcane, vegetables, and fruit, but these primarily rely on available water resources. Banchari's farming community relies heavily on Borewell based irrigation as their primary method of production. Rainfall and canals provide secondary support to irrigation because they are irregular and insufficient (CGWB, 2023). Hence, this creates a high dependency on continuous electricity and diesel to run the pumps, which primarily increases the cost of cultivation for small scale farmers.

Sanitation and Wastewater conditions

On field observations in Banchari village, it was disclosed that there is an absence of a formal sewage infrastructure (Field Observations, 2026). Wastewater from houses is discharged through open drains that run along the internal village lanes. Usually, these sewer channels overflow into village pathways which results in spilling of wastewater onto streets and grounds. This untreated sewage then heads towards traditional village ponds, i.e., Johads. Hakro, Rampokhar, Neemka, Mongar, Lihona Road, and Bisani Johad are among the ponds in Banchari that have become heavily polluted and turned into stagnant reservoirs. The water of these Johads becomes blackish green in color and has an extremely bad smell due to constant discharge of sewage and household waste (Field Observations, 2026). The bad part is that due to village ecosystems, these water bodies are often located nearby residential homes and schools, creating a constant health risk for the local population.

Ground Realities and the farmer's perspective

While interacting with people at the village chaupal (community hub), the deep-rooted anxieties among the farming communities about the future of agriculture and health came to light. Farmers have expressed a clear awareness of deteriorating soil health due to the extensive use of chemical fertilizers for years to increase yield, which has decreased crop quality (Field Interviews, 2026).
Within the farmers' community, there are many fears regarding:

- The rising cost of chemical fertilizers (Urea and DAP) (Department of Fertilizers, Government of India, 2024).
- More children are developing undiagnosed wheat and gluten allergies even with ready access to locally grown crops.The level of groundwater is drastically reducing during the hottest months of the year; therefore, the amount of time spent to irrigate will continue to increase. And will represent a bigger financial burden to producers (CGWB, 2022).

Therefore; The fears and experiences outlined above support the need for a local solution (decentralised solutions) to supply resources and to use available waste. Hari Pravah is an example of how decentralised community solutions can address waste and resource gaps, with relatively low investment cost when compared with urban development projects.

Technical methodology and framework of Hari Pravah

The Hari Pravah model is engineered as a decentralized wastewater treatment system (DEWATS) that follows a hybrid, passive design technique suitable for village conditions. It is ideal for village conditions with fluctuating wastewater volumes and organic loads because it depends more on natural biological processes and gravity-based flow. This is in contrast to centralized treatment systems, which depend on heavy machinery, skilled laborers, chemical additives, and a continuous power supply (Gutterer et al., 2009; Massoud et al., 2009).

The Multi Stage Treatment Process

The sewage treatment follows a three-stage process to ensure that the treated water is safe for reuse in agricultural and industrial purposes:

1. Primary Treatment (1° treatment**):** Also known as the Sedimentation and Physical Separation stage. In the first step, sewage that comes from the village first goes to a specialized settler or a septic tank, where physical separation takes place. In septic tank heavy matter present in the sewage settles to the bottom level of the tank, where these solids undergo initial anaerobic stabilization, while floating materials like fat, oil, scum, and grease will float at the surface level and will be kept in the same tank. The primary treatment processes help to decrease the physical burden on further treatment processes by allowing for the natural stabilization of solids without any mechanical intervention throughout the primary treatment (Tilley, et.al., 2014; CPCB, 2023).

2. Secondary Treatment: Also known as the Anaerobic Digestion stage. After the primary treatment, the effluent from stage one flows into an Anaerobic Baffled Reactor (ABR). The wastewater is made to flow through a series of chambers in an upward and downward flow pattern, moving through a sludge blanket, which is a dense population of microbial mass that breaks down dissolved organic matter with high efficiency without any need for mechanical aeration. For non-settleable solids, there are extra anaerobic filter units that are utilized where bacteria attach themselves to the gravel or supporting media to further enhance organic degradation. This treatment step significantly reduces biological oxygen demand (BOD) and organic pollution in the wastewater (Foxon et al., 2004; Gutterer et al., 2009).

3. Tertiary Treatment: Third stage also referred as the Polishing and Bio disinfection stage, is intended to produce water quality meeting standards for reuse. Effluent passes through a planted gravel filter, also known as a Root Zone Treatment System, which uses plants that grow in wetland areas, whose roots support microbial activity, filtration and nutrient uptake (Vymazal, 2010; UN-Habitat, 2008). To ensure that the water is free from pathogens, a solar powered UV unit or a chlorine contact tank is used to effectively disinfect the water by eliminating any pathogens so that the treated water is suitable for irrigation and other reuse purposes (WHO, 2006).

Integration with the Johad Based Village Ecosystem

A unique aspect of the Hari Pravah is that it has been designed to integrate with the already existing village ecosystem and its geography. For example, in Banchari, many johads (examples: Hakro, Bisani) are constructed within areas naturally considered low because of elevation. Thus, the system has been designed to be installed next to or within these locations, so that gravity feeds the flow and reduces the need for pumping infrastructure. The modular design allows for "Plug and Play" future expansion; as the village population increases, additional treatment changes can be added without disturbing the existing setup. Hence, this approach helps in solving the issue while respecting the existing village's cultural and spatial relevance of Johads.

The Hari Pravah Framework serves not only as a means of treating wastewater, but also provides a mechanism for recovering valuable goods from the waste stream in addition to water, in support of a circular economy at the village scale (Andersson et al., 2016; Drechsel et al., 2015).

- Biogas Recovery: Enclosed anaerobic digesters capture the methane generated during the anaerobic digestion of biomass (Mittal et al., 2018).
- Sludge Drying and Organic Fertilizer: Organic Fertilizer is made from Sludge Dried, which is removed from the treatment process and removed to Sludge Drying Beds for excess moisture removed via sunlight and evaporated to create organic fertilizer known locally as "Orgatlizer" for application by farmers to improve soil health.
- Storage and Distribution of Treated Water: To address the logistical challenges raised by farmers during village Chaupal discussions, a local treated water storage and distribution system, by gravity-fed, is part of the system and designed for easy access by farmers.

Resource Recovery and outcome Potential

The core advantage of the Hari Pravah model is its zero-waste framework. Each byproduct created as a result of the treatment process is fed back into another economy cycle creating a closed loop within the village ecosystem.

A shift to value added processes instead of solely viewing sewer management as a cost by adding resource recovery through biological treatment. By using resource recovery, two things are produced from the Hari Pravah framework that will address; 1) the environmental pressures, 2). Increasing input costs, and 3). Health Issues observed during field interactions at Banchari.

Reclaimed Water: Supporting Agriculture and Emerging Industry

The first product of the Hari Pravah framework is the production of reclaimed water which provides a consistent supply of water through irrigation for farmers in Banchari, while also looking toward the changing environment of the region.

- Applying Treated Wastewater for Agriculture: Research shows that using treated wastewater for irrigation has led to improved yields (12.5% to 28.1%) of crops like wheat and maize (Minhas et al. 2022; CPCB 2020). Also, using treated wastewater helps farmers have a reliable source for irrigation of their staple crops (like wheat and mustard) during dry times when it isn't raining. This constant supply of water will assist farmers in providing stable yields of crops, reducing their monthly diesel pump expense, and decreasing their increased hours of use for irrigation.
- Opportunities for Industry to Reuse: The rapid expansion of industrial growth in Banchari can be attributed to its location along National Highway 19 (NH-19) and the KMP Expressway, which has allowed for the growth of many manufacturing enterprises (e.g., Banjari Electric Vehicles) as well as logistics centers. These industries are currently under increasing pressure to comply with “Zero Liquid Discharge” regulations, thus Hari Pravah offers to provide businesses within the Banchari community with treated water for industrial processes (i.e., cooling water, dust control, and cleaning applications). The use of treated water reduces the impact of industry on the groundwater resources of Banchari and will also create an additional revenue source for the facility.

Recovery energy i.e. biogas to clean and Usable Fuel

Another outcome of the Hari Pravah model is biogas generation during the anaerobic treatment

process. This gas is used as a precursor to high value green fuels through a structured conversion process.

- Biogas production: During anaerobic digestion in the Anaerobic Baffled Reactor (ABR) and digesters, microorganisms break down organic matter present in wastewater and sludge and produce raw biogas consisting of methane and carbon dioxide (Mittal et al., 2018).
- The upgrading to Biomethane: To increase its usefulness, the raw biogas undergoes a scrubbing process that removes carbon dioxide i.e., CO_2, moisture and hydrogen sulfide i.e., H_2S. This results in biomethane, also known as Bio-CNG, which has higher energy content and cleaner combustion properties (Ministry of Petroleum and Natural Gas, 2018).
- Environmental and Social Impact: Methane is considered as a superior green fuel compared to diesel and firewoods because it possesses a simple molecular structure. When burned it goes under complete combustion, producing very low levels of smoke, ash or particulate matter.

Studies suggest that adoption of such systems can replace up to 83% of firewood usage in rural kitchens and on environmental level (Lewis et al., 2017), the use of biomethane can reduce carbon dioxide (CO_2) emissions by approximately 0.52 tons per month, help in improving local air quality in regions where AQI levels often remain high (MNRE, 2022).

Restoring Soil Health and Addressing food quality concerns using "Orgatlizer"

The solid digestate recovered from the treatment chambers is processed into Organic fertilizer i.e., Orgatlizer, a nutrient dense bio fertilizer. This helps in addressing the concerns of farmers raised during field interactions regarding soil degradation and rising dependence on chemical fertilizers.

- Soil Microbial Recovery: Chemical fertilizers such as urea and DAP, can weaken soil structure over time (Patra et al., 2016), while Organic Fertilizer helps in restoring soil microbial activity. It provides nutrients in a slow-release form, comprising. nitrogen, phosphorus, potassium along with trace minerals, help in improving long term soil fertility instead of focusing on short term yields alone (FAO, 2015).
- Health and Nutrition Link: By reducing the use of chemical fertilizers by farmers, the model focuses on producing grains using Organic fertilizers which aims to improve the natural protein structure of grains. This promotes safer and healthier food production. This is a critical intervention for the Banchari village, where undiagnosed wheat allergies have been observed. Promoting such "Clean food" helps in supporting public health, creates the possibility of a premium value proposition for village produce in nearby urban markets and also helps in protecting the health of the next generation.

Implementation Strategy and Institutional Feasibility

The Implementation of Hari Pravah is focused on more than just a technical methodology; it is built upon the deep-seated social fabric of the village and its daily functioning. The field experience has shown that in order for STP to succeed, it must:

- Respect the local decision-making process
- Allay the farmers' fears
- Create visible value for the village.

The community approach of Hari Pravah operates under the concept of “Profit with Purpose,” which differs from a top-down engineering model. The primary objective is to transform skepticism and doubting villagers into trusting villagers through clear communication, creating dialogue opportunities, demonstrating the economics of success, and sharing

economic benefit, all while honouring the traditional Banchari village culture with digital promotional efforts.

Stakeholder Engagement and the "Chaupal" Strategy

Chaupals and Baithaks are the most common and trusted gathering places in rural Haryana for collective opinion formation and decision making (Jodhka, 2012). In terms of institutional feasibility, the Hari Pravah initiative will employ a hyper-local trust building strategy:

- Sarpanch Strategy: The Hari Pravah project has a direct partnership with the Gram Panchayat and Sarpanch of Banchari to leverage local leadership attributes, as this is a credible foundation for success when embarking on anything new.
- Logistics Barrier Mitigation: While discussing treatment processes with farmers, many of them raised the question about how the treated water would reach their farm fields when wastewater treatment plants are far away. The model will utilize a decentralized localized piping network from the wastewater treatment facility to send treated water directly to the local clusters of farming activity.
- Live Demonstrations: Real time demonstration of cultural acceptance of the technologies is critical for gaining acceptance within the community. The model will include demonstrations of the treatment process using actual wastewater during events such as Dauji ka mela (a type of local fair) and/or other types of gatherings. Farmers will observe how the foul-smelling wastewater is transformed into clean, treated water as a result of the treatment process. This will provide the farmers with confidence about the new wastewater treatment technologies due to their ability to see and smell them.

Digital Advocacy and Village Ecosystem Networks

To extend both traditional venues of route to our project (such as having a Chaupal and Baithak) along with engaging the already established digital channels of Banchari Village:

- WhatsApp groups of Banchari: To ensure transparency and education to village members in regards to our project we will take advantage of the existing WhatsApp groups, such as "Yuva Ekta Banchari," for sharing project updates, effective water quality reports, and educational (short) videos on sustainable agriculture.
- Video testimonials: Another method we will utilize for sharing project success will be via the production of short video testimonials from the "early adopters" regarding the agricultural best practices they have utilized. Each testimonial will be an illustration of the reduction in input costs, improvement in soil quality, and sustainability of crop production associated with the success of sustainable agricultural practices. By providing real-life video success stories of farmers, they will have a better understanding of how to implement science-based methods of farming within their own day-to-day fieldwork.

Strategic Communication: The health and wealth Framework

The concept of Hari Pravah does not see communication as marketing, with its public health communications developed mainly around agriculture.

- Public Health Communication: The type of public health communication we are producing about the issues of food quality, the increase in allergies to wheat, and problems digesting food in a person's family is through conversation with the villagers in those areas, and that this issue appears to be related to the excessive use of chemical fertilizers used to farm (Pingali, 2012; Gupta et al., 2020). This type of communication

will address the villagers' concerns and anxiety regarding their community by linking soil health and, ultimately, the health of each village.

- The Organic Edge: The organic fertilizer i.e., Orgatlizer generated in the treatment, is positioned as a “Safe Soil” input. It will be communicated as a way to restore soil biology and maintain the natural protein structure of wheat. By appealing to the farmer’s concern for their family's health, the Hari Pravah model creates a value proposition which is hard to match for chemical fertilizers.

Human Capital and the "Future of Framework"

Hari Pravah is redefining rural labourers by helping the transition from traditional roles into Green Collar meaningful Jobs for local labourers (ILO, 2018). This help in preventing the migration of village youth in search of work to the nearest industrial hubs like Faridabad and KMP Expressway (Census of India, 2011; Bhagat, 2017):

- Micro Entrepreneurship: To increase employment among local youth, the model will create approximately 10 to 12 job roles, including positions such as Bioresource Managers and Technical Ambassadors.
- Product Ambassadors: Trained youth act as decentralized operators and communicators and will take care of STP maintenance, user guidance and help in building awareness by using their familiarity with local language, customs and farming routines.

Policy Recommendations

The Hari Pravah model shows that technical solutions alone cannot solve rural wastewater issues. Policies need to adapt to village ecosystems and realities to support resource recovery and to link agriculture with public health. This study proposed the following recommendations based on the field observations and their outcomes:

Decentralization of Regulatory Frameworks

At present in India, most environmental regulations are intended for large-scale municipal STP's, which present compliance challenges for decentralized initiatives such as Hari Pravah (Starkl et al., 2013 and CPCB 2021). The HSPCB should develop a new "streamlined licensing" category that focuses specifically on decentralized treatment systems.

- FastTrack CTE/CTO process: Decrease the bureaucratic delay of applying for the "Consent to Establish" and "Consent to Operate" (CTE/CTO) process through the fast-track permit system for passive biological treatment systems at municipal STP's, thus stimulating the use of these systems (HSPCB 2022).
- Develop standards for reuse: HPSCB needs to develop state specific guidelines or criteria for safe reuse of treated wastewater in agriculture (i.e., for irrigating crops) and as industrial cooling water, therefore reducing the regulatory burden on the local panchayats while protecting public health and safety (CPCB 2021).

Incentive Structures for Resource Recovery

Farmers in Banchari face rising costs of chemical fertilizers and the subsequent false selling practices of Urea and DAP at government distribution stores. The government needs to create balance for organic fertilizers.

- Subsidies for "Orgatlizer": This study suggest that bio fertilizers like Orgatlizer should be included in natural subsidy programs such as the PM-PRANAM scheme, so that these products are available at reduced prices; thus, providing smaller farmers an opportunity to use organic fertilizers (Ministry of Chemicals and Fertilizers, 2023).

- Recommendation on Integration: Study suggests that decentralized STPs need to linked with the Gobar Dhan scheme to provide monetary benefits, whereby the biogas produced from the STPs can be used to produce biomethane, thereby providing energy to the local communities (Ministry of Jal Shakti, 2023).

Linking Agriculture to Public Health

The "Chemical Health Nexus" observed in the Banchari during this study, especially the rising wheat and gluten allergies, shows the urgency for multi departmental coordination.

- Soil-Health-Nutrition Policy: The Ministries of Agriculture and Health should come together to promote "safe soils" inputs, encouraging the shift from synthetic chemical fertilizers to organic soil enrichment (NITI Aayog, 2021). This can improve the soil's nutritional value in the wheat and mustard growing areas of North India (FAO, 2015).
- Certification for "Clean Food": Recommend establishing an easy and affordable organic certification that could also contribute to improved market access in high value markets selling organic foods.

*Making Use of Both Corporate and Industrial Synergy to Maximise Power***:**

The close proximity of industrial corridors (KMP expressway and JBM Electric Vehicles) in Banchari village make it easy for both Banchari village and industry to form productive relationships with each other.

- Encourage local industries to meet their Corporate Social Responsibility (CSR) obligations for rural sanitation, specifically by supporting restoration of Johads through the Hari Pravah model (Companies Act, 2013).
- Develop Policies for Offtake Agreements. Include a policy that requires the purchase of locally produced biomethane by local industries to meet Green Logistics Fleet criteria (Ministry of Petroleum and Natural Gas, 2018).

Building Up Rural Human Capital

The success of the big employment initiative of Hari Pravah will depend on how well we formalize the jobs of the green economy (green-collar jobs), and develop entrepreneurship.

- Green Jobs Certification: Creation of vocational training programs focused on decentralized waste water management as a part of the Skill India Mission (Ministry for Skill Development and Entrepreneurship, 2015).
- Entrepreneurship Grants: Low-interest entrepreneurship grants can be provided to youth in rural areas in order to develop micro-enterprises. It will also help in managing and maintaining the resource recovery systems, and creating local business opportunities (Start-up Village Entrepreneurship Programme, 2016).

Conclusion

The Hari Pravah model shows that when sewerage systems are recognized as social assets, they can stimulate rural growth. This investigation on India's sanitation issue, when evaluated from a village perspective, reveals that authenticity in managerial innovation arises from grassroots measures that meet the social, ecological and economic demands. Modifying the long-standing method of 'dispose-by-collection' to a second-use option, i.e., 'recover-and-reuse', Hari Pravah creates closed systems which revitalise Banchari's wetlands like Hakro and Bisani Johads, while also addressing the critical challenges of water, energy and food experienced by Banchari's farmers (UN-water, 2017; Andersson et al., 2016.

Hoff, 2010; FAO, 2014) by reusing wastewater sourced as a biologically useful waste product in Banchari across other underdeveloped rural areas in the global south with minimal investment compared to costly statutory urban engineering. Using reclaimed irrigation water, upgraded biomethane, and Orgatlizers to develop a Triple Revenue Stream model for sustainable environmental solutions will validate that these types of solutions are also economically viable. This model provides both a technological approach as well as a solution to the "Chemical Health Nexus," or ways to decrease soil toxicity and increase healthier crop production. In developing the Hari Pravah system, the organic enrichment of the soil microbiome is being promoted as part of an overall improvement in public health through a focus on more than just solid waste management. Working with local community-based ecosystems using traditional methods (Chaupal) and newer technologies (e.g., WhatsApp) creates trust with the community and establishes long-term cultural acceptance. At last, the development of industry standards and job roles for green-collar jobs (International Labour Organisation, 2018). Employment for local youth will allow them to work as either bioresource managers or technical ambassadors, thus reducing the brain drain of youth migrating to urban centres to work in industries while creating new micro-business opportunities (Ministry of Rural Development, 2021). As Palwal and adjoining areas continue at a fast pace to develop as industrial hubs, the decentralized solution of this approach proves that rural areas can continue to develop alongside industrial centers without compromising their environment. The examples set by the Hari Pravah model illustrate that global management innovation begins at the lower levels, specifically the village (grassroots) level by providing protection of land, life, and livelihood through the use of clean technologies, community participation, and sustainable practices.

References

Andersson, K., Dickin, S., Rosemarin, A., Lamizana, B., Kvarnström, E., & McConville, J. (2016). Sanitation, wastewater management and sustainability: From waste disposal to resource recovery. Stockholm Environment Institute.

Bhagat, R. B. (2017). Migration and urban transition in India. Economic and Political Weekly, 52(8), 15–18.

Census of India. (2011a). District census handbook: Palwal, Haryana. Directorate of Census Operations, Haryana.

Census of India. (2011b). Primary census abstract: Haryana. Government of India.

Central Ground Water Board. (2022). Ground water year book – India. Ministry of Jal Shakti, Government of India.

Central Ground Water Board. (2023). Dynamic ground water resources of India. Ministry of Jal Shakti, Government of India.

Central Pollution Control Board. (2016). Guidelines on zero liquid discharge. Ministry of Environment, Forest and Climate Change, Government of India.

Central Pollution Control Board. (2022). Status of sewage generation and treatment in India. Ministry of Environment, Forest and Climate Change, Government of India.

Central Pollution Control Board. (2023). Guidelines for decentralized wastewater treatment systems. Ministry of Environment, Forest and Climate Change, Government of India.

Central Soil Salinity Research Institute. (2020). Soil salinity and agricultural sustainability in Haryana. ICAR-CSSRI.

Companies Act. (2013). The Companies Act, 2013. Government of India.

Department of Agriculture & Farmers Welfare, Haryana. (2022). District-wise crop statistics. Government of Haryana.

Department of Fertilizers. (2024). Annual report. Ministry of Chemicals and Fertilizers, Government of India.

Department of Land Records, Haryana. (2023). Land use statistics. Government of Haryana.
District Administration Palwal. (2024). Village and district statistical records. Government of Haryana.
Drechsel, P., Qadir, M., & Wichelns, D. (2015). Wastewater: Economic asset in an urbanizing world. Springer.

Food and Agriculture Organization of the United Nations. (2014). The water–energy–food nexus: A new approach in support of food security and sustainable agriculture. FAO.
Food and Agriculture Organization of the United Nations. (2015). Status of the world's soil resources. FAO.
Foxon, K. M., Pillay, S., Lalbahadur, T., Rodda, N., & Buckley, C. A. (2004). The anaerobic baffled reactor: An appropriate technology for on-site sanitation. Water SA, 30(5), 44–50.
Gupta, R., Saini, S., & Makharia, G. K. (2020). Dietary transition and gluten sensitivity trends in India. Indian Journal of Medical Research, 151(1), 11–14.
Gutterer, B., Sasse, L., Panzerbieter, T., & Reckerzügl, T. (2009). Decentralised wastewater treatment systems (DEWATS) and sanitation in developing countries. BORDA.
Haryana State Pollution Control Board. (2022). Consent management guidelines. Government of Haryana.
Hoff, H. (2011). Understanding the water–energy–food nexus. Stockholm Environment Institute.
International Labour Organization. (2018). World employment and social outlook: Greening with jobs. ILO.
Jodhka, S. S. (2012). Village society. Orient BlackSwan.
Lewis, J. J., Pattanayak, S. K., & Jeuland, M. (2017). Household biogas and fuel substitution in rural India. Global Environmental Change, 46, 1–10.
Makharia, G. K., Verma, A. K., Amarchand, R., Bhatnagar, S., & Das, P. (2011). Prevalence of celiac disease in northern India. Journal of Gastroenterology and Hepatology, 26(5), 894–900.
Massoud, M. A., Tarhini, A., & Nasr, J. A. (2009). Decentralized approaches to wastewater treatment and management. Journal of Environmental Management, 90(1), 652–659.
Minhas, P. S., Dotaniya, M. L., & Sarkar, A. (2022). Wastewater irrigation and crop productivity in India. Agricultural Water Management, 269, 107657.
Ministry of Chemicals and Fertilizers. (2023). PM-PRANAM scheme guidelines. Government of India.
Ministry of Jal Shakti. (2023). Swachh Bharat Mission (Grameen): Operational framework. Government of India.
Ministry of New and Renewable Energy. (2022). Annual report. Government of India.
Ministry of Petroleum and Natural Gas. (2018). SATAT initiative guidelines. Government of India.
Ministry of Rural Development. (2021). Rural employment and migration trends. Government of India.
Ministry of Skill Development and Entrepreneurship. (2015). National skill development mission. Government of India.
NCR Planning Board. (2021). Regional plan for the National Capital Region. Government of India.
NITI Aayog. (2019). Composite Water Management Index (CWMI) 2.0. Government of India.

NITI Aayog. (2021). Natural farming and agroecology in India. Government of India.
Patra, A. K., Chaudhari, S. K., & Biswas, P. P. (2016). Long-term fertilizer impact on soil health. Indian Journal of Agricultural Sciences, 86(12), 1486–1492.
Pingali, P. L. (2012). Green Revolution: Impacts, limits, and the path ahead. Proceedings of the National Academy of Sciences, 109(31), 12302–12308.
Sharma, P. C., Chaudhari, S. K., & Singh, O. P. (2018). Secondary salinization and crop productivity in Haryana. Journal of Soil and Water Conservation, 17(3), 211–218.
Singh, R. P. (2018). Soil health under intensive fertilizer use in India. Journal of the Indian Society of Soil Science, 66(1), 1–10.
Starkl, M., Brunner, N., & Stenström, T. A. (2013). Institutional challenges of decentralized wastewater management in India. Water Science and Technology, 67(12), 2724–2729.
Start-up Village Entrepreneurship Programme. (2016). Operational guidelines. Ministry of Rural Development, Government of India.