



Transforming Wastewater Treatment

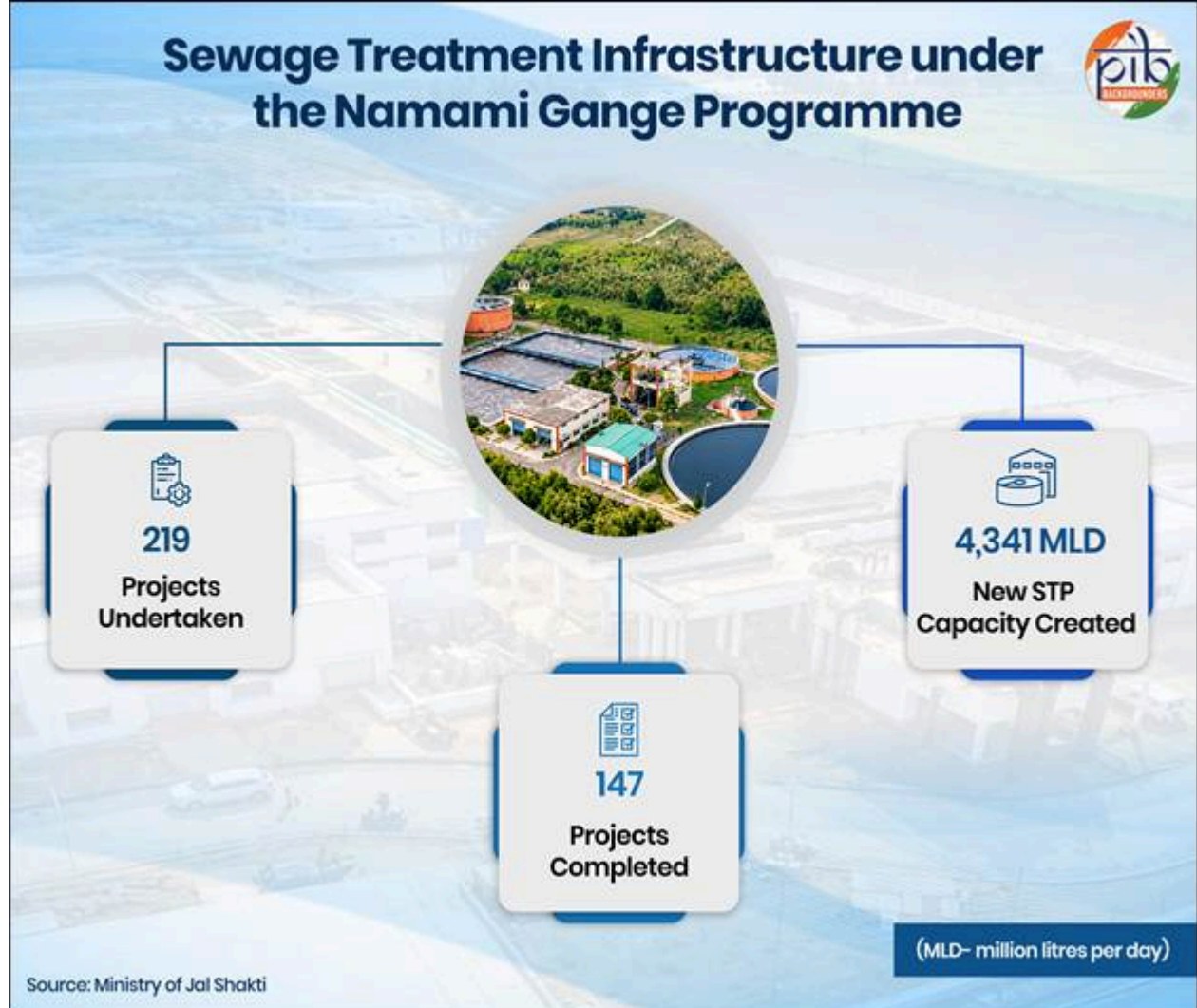
Technology and Innovation under Namami Gange

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Wastewater is generated daily through domestic and urban activities. As towns and cities expand, the volume of sewage requiring collection, conveyance and treatment also increases. Effective treatment therefore requires different technological approaches depending on the nature of sewage, local conditions and available infrastructure. In urban areas, sewage flows through underground networks to centralised treatment plants. However, areas without complete sewer networks require solutions for wastewater collected through septic tanks and other on-site systems. Treatment requirements also vary with sewage characteristics, available land, discharge standards and opportunities for treated-water reuse. Addressing these differences needs a combination of conventional treatment systems and innovative technologies suited to specific situations.

This approach shapes the **Namami Gange Programme (NGP)**, launched in 2014. It is an Integrated Conservation Mission with the twin objectives of effective abatement of pollution, conservation and rejuvenation of the National River Ganga. **Main pillars** of the Namami Gange Programme are Sewerage Treatment Infrastructure, River-Front Development, River-Surface Cleaning, Biodiversity, Afforestation, Public Awareness, Industrial Effluent Monitoring and Ganga Gram.

The programme places **sewage treatment infrastructure** at the centre of its pollution-abatement work. It combines the development of new treatment capacity and the adoption of different treatment technologies. The programme has undertaken **219 projects** worth an estimated ₹35,664 crore, of which **147** have been completed. It records interventions across 10 Ganga basin states, including development of 6,603 MLD of sewage treatment plant (STP) capacity, with 4,341 MLD created. These efforts expand treatment capacity while improving the performance of existing infrastructure.



Namami Gange's Technology-Neutral Approach

The Namami Gange Programme follows a technology-neutral approach, selecting sewage treatment processes according to local requirements. Adopted technologies include the Conventional Activated Sludge Process, Upflow Anaerobic Sludge Blanket (and its combinations with aerated lagoons), Sequential Batch Reactor, Moving Bed Biofilm Reactor, Fluidized Aerated Bed, and Food Chain Reactor. Other solutions include electrocoagulation, constructed wetlands and packaged systems such as Johkasou.

Activated sludge refers to a mass of microorganisms cultivated in the treatment process to break down organic matter into carbon dioxide, water, and other inorganic compounds.

Sequential Batch Reactor is a cyclic activated sludge treatment process which provides the highest treatment efficiency possible in a single-step biological process.

This flexibility allows treatment infrastructure to address varied conditions, including large urban centres, small habitations, hilly terrain and land-constrained locations. The programme also incorporates innovations such as NEREDA, Soil Biotechnology, on-site Advanced Oxidation Process-based treatment, multi-storey STPs and decentralised systems. Faecal sludge and septage management further extends treatment options beyond conventional sewerage networks.

Food Chain Reactor and Electrocoagulation



Food Chain Reactor

Food Chain Reactor (FCR) technology was introduced in India through the NGP. It improves upon the Activated Sludge Process and Sequential Batch Reactor by incorporating fixed artificial media and plant roots. Its advantages include a smaller footprint, lower power consumption and nutrient removal. The programme records **five operational FCR-based STPs**: two at Bhatpara, West Bengal and three at Prayagraj, Uttar Pradesh. Another plant at Bhagalpur in Bihar is under construction, with an approximate area of 175 square metres per MLD.



Electrocoagulation Technology Applied in Uttarakhand

Electrocoagulation and electro-oxidation represent another treatment approach introduced through the programme. Electrocoagulation is a **non-biological treatment process** that uses electric current and a coagulant metal anode to destabilise suspended and emulsified pollutants. These systems are suited to cold temperatures, hilly terrain and locations with limited access. Such systems have been implemented in Uttarakhand at locations like Badrinath and Chamoli, with **17 installations** recorded. These include a 0.05 MLD STP at Police Chowki, a 1.19 MLD plant at Vivekanand Colony and a 1.25 MLD plant at Pokhari Bend. These systems can therefore extend treatment infrastructure to locations where conventional approaches may be difficult to implement.

Onsite Treatment and Multi-Storey STPs

The programme has also explored treatment solutions that can work closer to the source of wastewater. An **Advanced Oxidation Process**-based pilot at Varanasi's Assi Drain was designed to treat excess wastewater onsite, avoiding long interception and diversion sewer lines. The approach uses systems with minimum civil infrastructure and faster execution. Treatment intends to improve water quality, increase dissolved oxygen, and eliminate odour. The model has an innovative financing arrangement. It links payments to the quantity of treated water and achievement of key performance indicators, with no upfront capital payment. This arrangement connects remuneration with treatment performance while allowing freedom in design and configuration.

Another example is the multi-storey sewage treatment plant at Muni Ki Reti, Chandreshwar Nagar. It is the **country's first four-storey STP** for a municipality built under the NGP. Limited land, three sewage drains, a stormwater drain and the site's location upstream of Rishikesh's Triveni Ghat made conventional construction challenging. The **7.5 MLD** plant occupies approximately **900 square metres**, using vertical construction to overcome space constraints. Its land requirement is around 120 square metres per MLD with biological nutrient removal, compared with 400 square metres per MLD for the cited conventional alternative. These examples show how treatment design can adapt to site conditions while meeting wastewater-management requirements.



Multi-Storey Sewage Treatment Plant at Muni Ki Reti

Nature-Based and Decentralised Treatment Solutions

Not every settlement requires the same scale of sewerage infrastructure. In smaller habitations, conventional networks and sewage treatment plants can be expensive, while limited land creates additional challenges. Under NGP, decentralised and nature-based solutions offer alternatives suited to such locations. **Constructed wetlands (CWs)** are engineered systems that use natural processes to remove pollutants under controlled conditions. A CW system comprises water, plants, growing media (substrate), soil and microorganisms.



Constructed Wetland Treatment

Bithoor in Uttar Pradesh demonstrates this approach. With a population of approximately 20,000, the Nagar Panchayat faced high costs for conventional sewerage infrastructure and a lack of suitable land for an STP. Constructed wetlands were selected following third-party appraisal as an emerging treatment technology. Six wetlands were developed directly on drains, providing in-situ treatment for approximately 2 MLD. This resulted in declining Biochemical Oxygen Demand (BOD) levels from around **75 mg/l** at the inlet to below **10 mg/l** in treated effluent. The technology is considered suitable for drains carrying small, dilute flows where sufficient length and width are available.

Johkasou provides another decentralised option for sewage treatment. It is a packaged treatment facility capable of treating domestic sewage to the desired regulatory and National Green Tribunal (NGT) norms. The system combines several sewage-treatment processes within a prefabricated, plug-and-play unit. Johkasou-based decentralised sewage treatment plants can be useful for low-flow applications, locations where civil construction is difficult and sites with limited space. It also includes locations where systems can be constructed underground. The systems have been used at multiple locations in Uttarakhand, with six installations recorded.

The systems reduce the need for full-time operators and daily sludge handling at the site. Multiple configurations, including cylinder-type and capsule-type options, cater to different flow requirements. Depending on the configuration, the treatment process includes screening, primary treatment, biological treatment, secondary settling, recirculation, disinfection and filtration. These features make Johkasou relevant to settlements where traditional sewerage infrastructure is difficult to build or supervise. Its use in Uttarakhand reflects the need to adapt decentralised sanitation solutions to local geography.

NEREDA: Efficient Biological Treatment

NEREDA is another biological wastewater treatment technology introduced through the NGP which uses aerobic granular sludge. It uses the same bacteria as conventional activated sludge but forms compact aerobic granules with good settling properties. The technology offers a smaller footprint, lower construction costs and reduced operating

expenditure. It has also demonstrated **power savings of approximately 50%** compared with the Activated Sludge Process and 20% compared with the Sequential Batch Reactor (SBR).

A **60 MLD** NEREDA-based STP at Pahadi Patna represents these advantages. Its bioreactor occupies approximately **1,900 square metres**, compared with 5,400 square metres for the cited SBR bioreactor requirement. NEREDA shows how advanced biological treatment can reduce space and energy requirements in larger installations.



NEREDA Reactor

Soil Biotechnology and Faecal Sludge & Septage Management



Soil Biotechnology-based STP at Devprayag

Soil Biotechnology provides a natural-treatment approach under the programme. This terrestrial wastewater-treatment system combines physical processes such as sedimentation and infiltration with biochemical processes. This removes suspended solids and organic and inorganic contents from wastewater. The system uses a suitable mineral constitution, native microflora, and bio-indicator plants as key components.

Also described as a Constructed Soil Filter, it can be built using Reinforced Cement Concrete (RCC), stone masonry, or soil bunds. Its elements include a raw-water tank, bioreactor containment, treated-water tank, piping and pumps. Depending on the desired water quality, the process can operate as a single-stage or multistage system. The approach minimises mechanical or moving equipment and facilitates easier operation. At Devprayag, a **1.2 MLD** Soil Biotechnology-based STP was constructed, with effluent standards based on NGT parameters.

Faecal Sludge and Septage Management addresses another part of the sanitation chain. At Chunar, Uttar Pradesh, a **10 kilolitres per day (KLD)** Faecal Sludge Treatment Plant (FSTP) pilot was sanctioned at a construction cost of ₹2.70 crore. Conventional interception and diversion networks and an STP were considered unfeasible due to high costs for the small habitation. Septic tanks and soak pits were prevalent, while drain flows remained low and some drains dried up. Following third-party appraisal, constructed wetlands or other nature-based solutions were identified as more suitable.

An FSTP does not replace an STP, as it treats periodic septage generated from soak pits. Co-processing enables septage from unconnected areas to enter the wider treatment system. It involves a receiving station for septage tankers and transferring the collected material into the network for treatment alongside city sewage.



Faecal Sludge and Septage Management

Energy Recovery, Sludge Management and Resource Use

Under Namami Gange, interventions focus on sludge management, energy recovery and reducing operational and resource requirements. Biogas generation through anaerobic digestion of sludge offers an opportunity for energy recovery. Anaerobic Digestion is the biological degradation of organic matter in the absence of oxygen. The biogas can be used for power generation. Varanasi's **140 MLD Dinapur STP** records an actual flow of approximately **110 MLD** and actual total power consumption of **4,20,000 units** per month. Biogas-based generation reached around **2,20,000–3,00,000 units** monthly, representing approximately **52% to 72%**. At the 80 MLD Naini STP in Prayagraj, biogas generation accounted for around 50% of daily power consumption. Other examples include projects at Jajmau in Kanpur and Bhagalpur, while a 220 MLD STP at Meerut is identified for Bio-CNG generation.

Sludge dewatering also contributes to operational efficiency. Dewatering is the separation of solids and liquids to increase the solid content of sludge by removing a portion of the liquid fraction. Volute Press (a sludge-dewatering device) was introduced at the 50 MLD Ramana STP to meet guaranteed energy-consumption and land requirements. Its energy efficiency and compact footprint have prompted consideration of replication. Together, these interventions extend wastewater management beyond pollutant removal to include residual sludge treatment and more efficient plant operation.

Green STPs: Energy Efficiency and Sustainable Operation

The long-term performance of sewage treatment plants depends on treatment standards, efficient operation and sustainable resource use. Under Namami Gange, several initiatives promote green and energy-efficient STPs.



Onsite Solar Power at an STP

On-site solar power was initially introduced at the **42 MLD Naini STP** to comply with guaranteed energy consumption. Its **1,000 KW** solar plant generates approximately **3,850 units** daily against a requirement of 5,700 units. At the 80 MLD Naini STP, solar generation contributes around 1,400 units daily, while biogas supplies another 4,500 units against a total requirement of about 8,900 units. Other installations and projects include the 16 MLD Jhunsi and 14 MLD Phaphamau STPs, alongside projects at Bareilly, Bhagwanpur, Vrindavan, Hathras, Shamli and Saharanpur.

A **220 MLD Meerut STP** has also been proposed as a Green STP, with **100%** solar power envisaged for the plant and associated facilities. A 10 MW offsite solar plant was being considered by the concessionaire, with electricity supply proposed under the Government of India's Open Access Policy.

Sludge treatment also contributes to sustainability. A sludge incineration pilot at Rishikesh explores thermal stabilisation and volume reduction. Dewatered municipal sludge containing about **20% solids** can be dried to around **90% solids** using hot air. The dried sludge is then oxidised in a hot-air generator. The resulting dry ash is not bio-manure, but stabilised ash can be considered for making fire bricks or concrete. At Muni Ki Reti, the pilot was intended to address sludge disposal challenges arising from limited land availability. Together, these efforts combine renewable energy, efficient equipment and improved sludge management to strengthen the environmental and operational sustainability of STPs.



Sludge Treatment at Muni Ki Reti

Rehabilitation, Trunk Sewers and Long-Term Performance

Creating new treatment capacity must be complemented by rehabilitating existing STPs and trunk sewers. Ageing equipment, non-compliance with treatment standards and missing tertiary-treatment components can necessitate upgrades. Under Namami Gange, rehabilitation works address these issues across multiple locations. Examples include the **80 MLD Naini STP** in Prayagraj, with electro-mechanical works, biogas power and OCEMS. The **130 MLD Jajmau STP** in Kanpur received civil and electro-mechanical rehabilitation, biogas power, chlorination and OCEMS.

Trunk sewer rehabilitation is similarly critical as it addresses siltation, damage and punctures in ageing networks. In Varanasi, a 7-km old brick trunk sewer, up to 2,400 mm in diameter, was taken up using a Glass Reinforced Pipe liner. In Kanpur, 9.3 km of old brick trunk sewer, up to 2,250 mm in diameter, was taken up using Machine Wound Spiral Lining.

The programme also uses the **Hybrid Annuity Model (HAM)- based Public-Private Partnership (PPP)** and One City/Cluster–One Operator model to integrate new and existing sewage infrastructure. Construction-linked payments are combined with performance-linked payments over **15 years**, promoting accountability and sustained operation. Under this model, 31 projects covering 1,955 MLD were taken up. Of these, 11 projects covering **454 MLD** have been completed, while 6 projects covering **235 MLD** are in an advanced stage of completion. The focus on rehabilitation, operation and maintenance makes wastewater treatment a continuing service rather than a one-time infrastructure activity.

From Sewage Treatment to Sustainable Wastewater Management

Namami Gange's approach to wastewater treatment combines infrastructure, diverse technologies, decentralised solutions, rehabilitation and long-term operation. Conventional and advanced treatment processes, nature-based systems and emerging technologies address varied local requirements. Performance-based operational models, resource recovery, energy efficiency, sludge management and treated-water reuse strengthen the overall treatment framework. Ultimately, the objective extends beyond building STPs to creating sustainable wastewater-management systems that ensure effective treatment, reliable performance and resource recovery across the river basin.

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