Whitepaper on brainstorming session on

“Roadmap to Yamuna Cleaning”

Held on 8th May at IIT Delhi

Flagship programme of the Office of the Principal Scientific Adviser to the GoI

Contents

List of participants

Name	Designation	Organisation
Dr. Monoranjan Mohanty	Adviser/ Scientist G, Lead-Waste to Wealth Mission, **(Chair)**	O/o PSA to GoI
Dr. Vishal Choudhary	Scientist F, S&T cluster co-ordinator, **(Co-Chair)**	O/o PSA to GoI
Ms. Shipra Misra	CEO **(Organiser)**	DRIIV
Dr. Pawan Labhasetwar	Prof. of Practice	IIT Madras (Frmr Chief Scientist, CSIR- NEERI)
Dr. Paras Pujari	Sr. Principal Scientist	CSIR-NEERI
Dr. Girish Pophali	Chief Scientist	CSIR-NEERI
Dr. P. S. Brahmanand	Project Director	WTC, ICAR-IARI
Dr. (Mrs.) Susama Sudhishri	Prof. & Principal Scientist	WTC, ICAR-IARI
Dr. Khajanchi Lal	Principal Scientist	WTC, ICAR-IARI

1. Context:

The cleaning of the Yamuna holds paramount importance in ensuring water security for the city of Delhi. As the lifeline of the National Capital Region (NCR), the Yamuna serves as a primary source of water for both domestic and industrial purposes. However, rampant pollution has severely compromised the quality of water in the river, posing significant threats to water security in Delhi. Less ground water recharge and encroachments in riverbeds have severely affected the water carrying capacity of Yamuna. The situation is worsened by little or no flow in non-monsoon months due to lack of indigenous water resulting in the presence of undiluted pollutants. Efforts to clean the Yamuna are therefore indispensable for safeguarding water security in Delhi. Moreover, the cleaning of the Yamuna is not just a matter of environmental stewardship but a fundamental necessity for preserving the well-being and prosperity of Delhi.

This paper summarizes the discussion of the brainstorming session towards a comprehensive understanding of the multifaceted sources of pollution and reduced flow plaguing the Yamuna focusing mainly on the **22km**-long stretch running downstream from **Wazirabad to Okhla barrage** as it contributes to more than 50% of the pollution load. Ongoing efforts and governmental initiatives are also highlighted along with recommendations from the participating experts on how engagements with industries and relevant administrative authorities can help in identification and subsequent deployments of viable solutions that are both technologically advanced and economically feasible for a 'clean Yamuna'.

2. Summary of discussion

Ms. Shipra, CEO & MD DRIIV, opened the session emphasizing the objective of the discussion as to develop a common understanding of the sources of pollution affecting Yamuna in the Delhi stretch. Leveraging its vast S&T ecosystem, DRIIV aims to tackle some of the interconnected problems spanning across Delhi and neighboring Haryana on cleaning stretches of the Yamuna. In this multistakeholder venture, DRIIV envisages working collaboratively with industry-academia-relevant govt. bodies.

2.1 Pollution of Yamuna: current scenario

The pollution levels in the Yamuna River are distressingly high, with various types of pollutants severely impacting its ecosystem and the communities dependent on it. As discussed during the brainstorming session, one of the most polluted stretches of the Yamuna River is commonly identified as the stretch passing through Delhi, particularly from **Wazirabad to Okhla**. This segment of the river receives significant inputs of untreated/partially treated sewage, industrial effluents, and solid waste from surrounding urban areas, industries, and settlements. The concentration of pollutants in this stretch is exceptionally high, resulting in severely degraded water quality, foul odors, and visible pollution.

2.1.1 The primary pollution load of the Yamuna in the Delhi stretch stems from a multitude of sources:

- Industrial effluents (<50%)
- Untreated sewage from urban settlements
- Runoff from basins and interbasins

Dr. Vishal Choudhary, Scientist F, S&T cluster coordinator, Office of the PSA to the GoI, deliberated on how the pollution of the Yamuna River is a multifaceted issue with contributions from various sectors and industries playing a significant role. A **22km**-long stretch (~2% of Yamuna's total length) running downstream from **Wazirabad to Okhla barrage** contributes more than 80% of the Yamuna pollution load. He stated that in this particular segment, pollutants from industrial discharge, municipal sewage, untreated wastewater from drains are directly dumped in the river. Although the drains have interception and diversion provision of sewage to the nearby STPs, the quality of the treated effluents discharged back in the river is non-compliant to CPCB standards.

Dr. Pawan Labhasetwar, Prof. of Practice, IIT Madras (Former Chief Scientist, CSIR-NEERI), explained how the Yamuna bears a heavy pollution load upstream of Wazirabad, exacerbated by contamination from Haryana (540MLD wastewater out of which only 260MLD is treated) and about the complaints from Delhi Jal Board's (DJB) on elevated percentage of ammonia. Oil contaminated wastewater is also a major bottleneck.

Dr. Choudhary emphasized the significant role industrial sector can play in cleaning Yamuna by adopting viable and economically feasible technological interventions. Since this industrial belt mainly comprises of chemical and textile industries polluting the river by elevating the concentration of heavy metals, sustainable technologies managing industrial wastewater should be developed and adopted. Although available technologies like the amphibious technology implemented in Barapullah drain during a pilot study, are relevant for municipal waste management (for MCD) are relevant, they may not be directly applicable to the unique challenges posed by industrial waste.

Dr. P. S. Brahmanand, Project Director, WTC, ICAR-IARI explained that concentration of pollution, primarily from municipal and industrial waste, poses significant challenges, particularly concerning effluent-heavy industries like chemical, leather, and tile manufacturing. While viable technologies exist for municipal waste management, addressing industrial waste remains daunting.

Dr. Susama Sudhishri, Professor and Principal Scientist, WTC, ICAR-IARI emphasized upon the components of hydrologic cycle with major portion runoff from different land uses in catchment/basin area of the river. Due to climate change, the intensity of rainfall is increasing, so runoff and sediment flowing to the river is also increasing. So obviously decreasing the carrying capacity of Yamuna River. Therefore, emphasis should be given to catchment treatment. Other sources of pollution like disposal of grey and blackwater to the river system also caused the problems. Another problem of use heavy doses of fertilizers which causes the problems of pollution. So, there is the need for remediation for both point and non-point source of pollutions.

2.1.2 The water quality is heavily impacted by the discharge from 6 major drains, including Najafgarh, Barapullah

Dr. Manoranjan Mohanty, Adviser / Scientist G, Office of the Principal Scientific Adviser (PSA) to the Government of India (GoI), Lead, Waste to Wealth Mission introduced the severity of pollution load with the **6 km stretch** of the Yamuna river passing through Delhi being the most polluted sections, heavily impacted by the discharge from **6** major drains. These drains, including Najafgarh Drain, **Barapullah Drain** (Dept. of Irrigation, NCT Delhi) etc., collectively carry a substantial amount of untreated sewage, industrial effluents, and solid waste into the river. Despite these drains being channelized to multiple sewage treatment plants (STPs), the sheer volume of pollution in these drains, coupled with partial treatment of sewage, inadequate infrastructure and enforcement, continues to challenge remediation efforts. He mentioned the implementation of **DRAINMASTER** technology in the Barapullah Drain to mitigate pollution and improve water quality. As part of a pilot project, this amphibious technology cleaned a stretch of 3 km, due to which water flow was increased.

Dr. Brahmanand re-emphasized the severity of the situation during the lean season of Yamuna. Only 10% of the flow out of the total volume of water is reaching Delhi. A total of **22 drains** are connecting Yamuna, some are partially treated and some untreated. The inability of STPs to handle Delhi's pollution load has severe repercussions on the Yamuna's water quality, with partially treated sewage being discharged into the river. Regulatory measures are imperative to address this pressing issue. Significant funds were allocated by the Government of Delhi to rejuvenate Najafgarh drain which is a major source of pollution of Yamuna river and which has long been plagued by pollution and encroachment, posing environmental and public health risks.

2.1.3 Inadequate sewage treatment infrastructure of Delhi

Dr Pawan explained how the inadequate sewage treatment infrastructure in Delhi, is a major contributor to the pollution of the Yamuna. The existing sewage treatment infrastructure is insufficient to treat all the sewage generated daily, resulting in the discharge of untreated wastewater, laden with organic matter, heavy metals, pathogens, into the river.

This issue is compounded by the **underutilization of sewage treatment plants** (STPs), resulting in partially treated sewage exacerbating the pollution problem.

Dr. Girish Pophali, Chief Scientist, CSIR-NEERI, underscored the findings of the institute on the performance evaluation after 15 years of CETPs, predominantly catering to chemical industries. He highlighted the necessity for a holistic approach which will effectively prevent loads from municipalities and industries. To maintain the adherence to NGT norms for sewage disposal into water bodies, operational-level solutions for STPs need to be looked into, and improved operation and maintenance practices need to be adopted for CETPs to ensure adequate treatment of sludge and sewage.

Dr. Khajanchi Lal, Principal Scientist, WTC, ICAR-IARI, also touched upon the issue of industrial wastewater from STPs in the river posing critical health hazards. In addition to being discharged into water bodies, industrial waste is being directly absorbed into groundwater, as exemplified in Panipat, where groundwater became undrinkable, leading to serious illness among five laborers due to its consumption. The industrial effluent must be treated at source and should not be allowed to mix with municipal waste otherwise it will result in huge volume of wastewater of complex composition nearly impossible to treat.

Dr. Sudhishri emphasized upon the construction of series of check dams and treatment of wastewater in the upstream of check dams can reduce the direct inflow of industrial wastes to Yamuna river.

2.1.4 Severity of water shortage problem: situation worsened during the sewage flow in lean season

Shedding light on the flow of Yamuna during lean season**, Dr. Pawan** mentioned that the flow is approx. 1000MLD (10%) primarily comprising of sewage which can be effectively reduced by reducing the water drawl from Wazirabad and thereby increasing freshwater in the Delhi stretch. This again emphasized the magnitude of pollution load being put by inefficient treatment of sewage **upstream of Wazirabad** in the river. The discharge of un-(partially)treated sewage can alter the natural flow dynamics of the river. Accumulation of sewage can lead to sedimentation and blockages, reducing the effective flow capacity of the river. Balancing sewage treatment & freshwater influx are crucial for Yamuna's sustainability.

Augmenting water supply is also imperative, especially considering DJB's staggering 50% water loss, a significant portion of which could be mitigated by collaboration with industries.

Dr. Paras Pujari, Sr. Principal Scientist, CSIR-NEERI, discussed about addressing the multifaceted challenges of Yamuna pollution requires a comprehensive approach, encompassing efforts to dilute the loads on the river, regulate its flow, and establish robust regulatory and administrative frameworks. He emphasized the importance of engaging experts to tackle issues like water loss through leakage reduction. Leakage from the pipes can be detected through a comprehensive Subsurface Utility Engineering (SUE) study.

Dr. Pawan further reiterated the criticality of reducing water loss and how innovative sustainable solutions can be leveraged in this scenario, with Barapullah Drains serving as test beds for startups to showcase their water management solutions.

Dr. Choudhary pointed out that this topic can be deliberated on the 21st, during **the Industry Connect Meet** by the Office of PSA for potential industrial engagements (particularly chemical and petrochemical industries).

2.1.5 Lack of catchment protection, encroachments along the riverbanks and floodplains hinder the natural flow of the river

Dr. Brahmanand mentioned that catchment areas play a vital role in water resource management, as they serve as the primary source of surface water for rivers, lakes, and reservoirs and we need to concentrate on integrated catchment treatment plan. Desilting is also crucial in maintaining the ecological balance, improving water quality, and enhancing the storage capacity of reservoirs, lakes, and rivers in catchment areas. The high **silt content upstream of Warizabad**, exacerbated by a flow rate exceeding the treatment capacity, underscores the urgent need for intervention to mitigate silt accumulation. **Dr. Pawan** also pointed out the importance of **catchment protection** which is essential for ensuring the long-term health and rejuvenation of waterbodies. In this aspect, Najafgarh lake can be taken up as an example as per directives from National Green Tribunal (NGT). Najafgarh lake has long been plagued by pollution and encroachment, posing environmental and public health risks.

Dr. Sudhishri, touched upon several critical points while addressing the issues surrounding surface water, groundwater, and wastewater management. She emphasized upon the effect of topography and land uses on the catchment ecosystem which plays a major role for runoff and sediment flow, lack of treatment decreasing the storage capacity in waterbodies/reservoirs and carrying capacity of rivers. In areas with higher slopes, **over-exploitation** poses a significant challenge, worsened by settlements causing lakes like Damduma to dry up. Due to deforestation most of the springs dried up. **Groundwater discharge** surpasses recharge due to population density, tubewell density necessitating regulations on tube well construction. Most of the waterbodies in catchments are in very bad shape (w.r.t. dimensions of structures, availability of water (quantity and quality), defunct/less use. In the river banks of Yamuna there is the problems of stream bank erosion, it is high during flood recession and after heavy rainfall. So, there is utmost importance for catchment treatment as well as river bank erosion control measures with different bio-engineering measures and afforestation, different agroforestry models, rejuvenation of waterbodies and wetlands to reduce runoff, sediment, enhancing groundwater recharge as well as enhancing productivity, increasing streamflow and springflow.

2.1.6 Unavailability of technological interventions tailored towards industrial sludge treatment

Dr. Choudhary mentioned that although available technologies can be effective for municipal waste management, they might not be as effective particularly for chemical and textile industrial waste being discharged in the river. It's imperative to develop new technological interventions tailored specifically for industrial waste management, including chemicals, dyes, and acidic waste. These solutions must not only be economically feasible but also capable of reducing pollution load on a daily basis.

Dr. Brahmanand stated that the main challenge in removing heavy metals from sludge lies in finding effective methods, as adsorption-based technologies may not always be feasible.

2.1.7 Poor reuse practices for treated wastewater

All the experts emphasized on the sustainable practices of treated wastewater, which if properly managed, can be a valuable resource for non-potable uses such as irrigation, industrial processes, and groundwater recharge. However, in Delhi, a significant portion of treated wastewater is not reused but instead discharged into Yamuna or sewage drains.

2.1.8 Inadequate coordination among various agencies responsible for managing Yamuna pollution, coupled with lax enforcement of regulations, undermines pollution control efforts

In Delhi, several agencies are responsible for the cleaning and management of water bodies, including the Yamuna River. Dr Sudhishri pointed out the criticality of Convergence and linkages among relevant departments, emphasizing holistic approach for problem-solving.

2.1.9 Lack of multistakeholder collaboration with industrial engagements and holistic approach: pilot studies done in isolation

Many successful pilot studies have been conducted in the Delhi stretch of the Yamuna River to address various environmental challenges and improve the river's health. Some noteworthy examples are implementation of **DRAINMASTER** technology in the Barapullah Drain to mitigate pollution and improve water quality, artificial reservoirs on the Yamuna flood plains to conserve rainwater etc. This signifies the fact that although there is no dearth of sustainable technologies, optimal benefit of S&T can only be leveraged through a strategic roadmap for 'Clean Yamuna' involving relevant stakeholders and with an integrated approach.

2.2 Recommendations towards a strategic roadmap 'Cleaning Yamuna' (the 22km Delhi stretch)

2.2.1. Stakeholder mapping: Fostering industrial engagement and regulation to mitigate industrial pollution

Dr. Choudhary emphasized the significant role industrial sector can play in cleaning Yamuna by adopting viable and economically feasible technological interventions. By systematically mapping and engaging stakeholders in Yamuna cleaning efforts, meaningful partnerships can be fostered by leveraging Cluster's network for achieving sustainable and inclusive outcomes.

Dr. Pawan emphasized the critical roles of institutional management (DPCC, DJB, MCD) and industrial engagement as well as major bottle necks of managing oil contaminated wastewater in this regard. He pointed out the importance of collaborations with Ministry of Housing and Urban Affairs (MOHUA) and Niti Aayog to signify governmental support and direction in this endeavor.

2.2.2. Ensuring proper operation and monitoring of sewage treatment plants to effectively treat wastewater before discharge

Dr. Pawan mentioned that addressing the challenges of inadequate sewage treatment comprehensively requires concerted efforts to reduce pollution inputs, optimize water management strategies, and enhance collaboration between stakeholders to ensure sustainable water usage and environmental preservation in the region. Redirecting more sewage load strategically to existing STPs rather than constructing new ones and ensuring that the maximum capacity of existing STPs is utilized, will also have significant impact on the pollution load of the river. Effective maintenance and regular monitoring of the plants are essential to ensure their continued operational efficiency. Additionally, promoting the optimal utilization of common treatment plants (CTPs) and treatment at the industry level can further improve pollution level.

Dr. Pophali pointed out that improvement in Yamuna water quality during the COVID-19 lockdown was attributed to the temporary shutdown of industries and reduced human activity. This underscores the potential for similar positive outcomes with the implementation of proper regulatory measures. By enacting and enforcing stringent regulations on industrial discharge and sewage treatment, authorities can replicate the improvements witnessed during the lockdown period. He suggested the potential implementation of recommended technologies from Clean Ganga Mission can improve the pollution crisis. He highlighted the necessity for a holistic approach which will effectively prevent loads from municipalities and industries. To maintain the adherence to NGT norms for sewage disposal into water bodies, operational-level solutions for STPs need to looked into, and improved operation and maintenance practices need to be adopted for CETPs to ensure adequate treatment of sludge and sewage.

2.2.3. Industrial sludge, heavy metal removal and fixation ("closing the loop" approach) to reduce toxic contamination in the river.

Dr. Brahmanand suggested an efficient approach involves fixing the metals in a stable form. For instance, chromium-contaminated water could potentially be reused in silviculture, where the metal can be utilized without posing environmental risks. Additionally, heavy metals can be immobilized by incorporating them into building materials such as bricks, which helps prevent their release into the environment.

Platforms like DRIIV can play a crucial role in tech evolution by facilitating the integration of innovative solutions into real-world scenarios.

Ms. Misra emphasized the potential of the phycoremediation technology from the Cluster ecosystem for industrial sludge management.

Dr. Brahmanand further pointed out that Najafgarh's sludge issue necessitates innovative solutions like phycoremediation for small-scale treatment, but an integrated plan is crucial, starting with desilting.

2.2.4. *Managing water quality, quantity and rejuvenation holistically: implementing catchment protection, measures to prevent contamination*

Dr Mohanty pointed out the critical role of rejuvenation of waterbodies connected to the Yamuna to enhance ecosystem health and biodiversity. He further mentioned **AlphaMERS**, an indigenous technology which can potentially be used for rejuvenation and cleanup of Yamuna. He offered to connect the Cluster with both the technology providers.

Dr. Pujari, discussed about how initiatives such as the Swachh Bharat Mission play a pivotal role in contributing to the cleanliness of the Yamuna. He emphasized the importance of engaging experts to tackle issues like water loss through leakage reduction. Furthermore, reducing the overall load on the river necessitates aggressive programs involving relevant organizations, acknowledging that this complex issue cannot be tackled in isolation. Integration of new technologies, catchment protection measures, and radar-based monitoring are the other crucial areas to focus on. He offered to make necessary connections to leverage relevant technologies, with platforms like DRIIV to propel efforts forward. There is a strong need for strengthening interventions like rainwater harvesting and recharge in the city of Delhi to reduce the dependency on the supply from Yamuna. It is necessary that the flow in Yamuna is adequate to assimilate the load from different sources.

Dr. Sudhishri suggested implementing a network of new construction waterbodies and check dams, rejuvenation of existing structures and catchment treatments with different *in-situ* water conservation practices can aid in water storage, groundwater recharge and carrying capacity of streams and river. **Cost-effective bioengineering techniques** with natural and planned vegetation for landscaping Yamuna banks will also be beneficial. Agricultural and industrial pollution mapping, along with hydrological zone mapping, are also critical. Addressing Delhi's drainage shortcomings by creating gaps for groundwater recharge alongside roads is essential along with rooftop rainwater harvesting. According to her desilting plans and erosion control measures tailored to different landscapes are vital components of a circular economy strategy for Yamuna. She emphasized that WTC has developed different techniques and their expertise in this aspects which can be implemented.

Dr. Brahmanand mentioned that WTC is dedicated to addressing water-related challenges, with a particular focus on treatment of **catchment areas** which are very critical in Yamuna cleaning. Multistakeholder involvement and showcasing technological capabilities in synergy can facilitate problem-solving. NEERI's expertise holds promise for playing a pivotal role in water quality management. Initiating a pilot project on desilting activities at **Najafgarh Lake** could serve as a testing ground for innovative solutions. Groundwater recharge initiatives along the Yamuna are also crucial, particularly considering water crisis witnessed in cities like Bangalore, where water bodies have depleted.

Dr. Lal suggested that groundwater contamination can be mitigated partially by allocating small portions of land adjacent to the STPs to farmers for relevant afforestation activities like planting of nonedible crops or disposing of wastewater in tree plantation having high rate of transpiration. To enhance the economic feasibility of this approach public bodies should be roped in. Moreover, employing treated water in agriculture serves to remove nutrients before reintroducing it into the river system. He further recommended innovative methods such as fishing nets with adsorption technology aid in the removal of floating materials, while **floodplain filtration systems** require proper regulatory control over the rate of flow to be effective. Additionally, decentralized technologies for sewage sludge collection contribute to a more efficient and sustainable wastewater management system. Temporal and spatial sampling of the river Yamuna in the polluted stretch and drains from the source to sink for determining the water quality should also be done. It will help in identification of hot spots for effective interventions. Land cover, land development and tree plantations along the banks of Yamuna may result in further reduction of pollutant load thus assist in improving the quality of water in Yamuna.

2.2.5. Formation of expert committees for technology validation and informed decision making

Dr. Pophali, emphasized the fact that any technological intervention aimed at addressing a specific issue must undergo rigorous evaluation to ensure its effectiveness and reliability, ultimately striving for a foolproof system.

Ms. Misra suggested setting up an evaluation committee providing validation to ready-to-implement technology interventions and deployment of the same addressing the pollution issue through the Cluster platform. She highlighted the unique role DRIIV can play as a cluster in identifying appropriate technology and making recommendations on policy interventions.

Dr. Vishal Choudhary pointed out that given the **multi-departmental involvement** in managing the Yamuna and waterbodies across Delhi NCR, the **Office of the LG** could serve as a focal point for assistance and coordination. Presenting readily adaptable technologies to the Hon'ble LG would facilitate addressing the challenges associated with these water bodies effectively involving relevant stakeholders. He emphasized establishing a committee for validation of relevant technologies. Piloting these technologies will assess their effectiveness and scalability. Mapping efforts are essential to track the dispersion of effluents and hazardous waste, leveraging existing data (hazardous Waste Management Rules and portals maintained by Ministry of Labour). By utilizing available data and coordinating efforts through a dedicated committee, DRIIV as an S&T Cluster will facilitate informed decision-making and enhance our capacity to manage Yamuna issues effectively.

2.2.6. Introduce properly validated relevant technological interventions tailored to manage industrial waste and reduce pollution

Ms. Misra emphasized the role of the Cluster in scouting for ready-to-deploy technologies and requested Dr. Choudhary to share relevant documents providing information on categorization and sector-wise segregation of pollutants of Yamuna.

2.2.7. Utilize GIS mapping to identify pollution hotspots and prioritize remediation efforts

Dr. Pophali mentioned that geospatial mapping plays a crucial role in identifying and understanding the contributing areas to Yamuna pollution. By utilizing satellite imagery, GIS data, and other geospatial technologies, it becomes possible to pinpoint sources of pollution such as industrial discharge points, urban runoff, agricultural runoff, and sewage outfalls along the river basin. This mapping helps authorities to prioritize areas for intervention, implement targeted pollution control measures, and monitor the effectiveness of remedial actions over time.

Dr. Brahmanand explained that understanding **land-use** and **land-cover** patterns is crucial for optimal crop planning and for effectively managing Yamuna pollution, and leveraging remote sensing and GIS technologies provided by agencies like **ISRO** and **NRSA** can offer precise insights into geographical locations of the pollution hotspots and analysis of existing cropping pattern.

Dr. Sudhishri also emphasized upon the land use land cover as well as waterbodies change detections in basin, catchments and interbasins of Yamuna river using Remote sensing, GIS and hydrological models to reduce the pollution in Yamuna

2.2.8. Looking into the success stories for relevant technologies: Clean Ganga Mission and deployments in other cities

Aligning the efforts with the Clean Ganga Mission, particularly through experts like Prof. Tare from IIT Kanpur, can offer insights into applicable technologies, as suggested by Dr. Brahmanand.

Effective mechanisms for reusing treated water to prevent its discharge into drains, as exemplified by the practices in Nagpur should also be adopted. All these endeavors align with the broader **Clean Ganga Mission**, emphasizing the importance of holistic approaches to water conservation and management.

The situation of waterbody deletion in **Bangalore** was effectively controlled by utilizing treated wastewater to replenish these water bodies, highlighting the potential for sustainable water management practices. Dr. Brahmanand suggested collaborations with institutions like **IIT Roorkee** for ground water quality improvement, bringing in skimmers & tagging with DJB for augmenting storage capacity would be beneficial.

3. Action points for DRIIV

3.1 DRIIV offers an integrated S&T platform for comprehensively tackling the pollution and degradation of Yamuna by combining various strategies and initiatives across multiple sectors:

- **Stakeholder mapping**: DRIIV will identify key players (innovators, technology experts, government agencies, industries and other stakeholders including public participation) for a comprehensive understanding and to collectively work towards Yamuna's restoration leveraging the Cluster's impactful member base spanning sectors.
- **Technology validation committee**: Establishment of an expert committee leveraging DRIIV's vast ecosystem for validation of ready to deployable technologies.
- **Providing testbeds for sustainable technologies**: DRIIV will facilitate pilots with public bodies where Barapullah and Najafgarh drains can be utilized as testbeds for startups to assess effectiveness and scalability of their technologies.
- **Sewage and wastewater management**: Drafting feasible options to upgrade existing sewage treatment infrastructure to treat domestic and industrial wastewater effectively (including hazardous chemicals, heavy metals etc) will be done by DRIIV. Recommendation of monitoring mechanisms to ensure operation, compliance and accountability will also be made.
- **Innovative and sustainable solutions**
    - **Industrial pollution control**: DRIIV will scout for technologies tailor made for industrial waste management and implementing strategies to incentivize industries for adopting eco-friendly practices.
    - **Catchment protection and restoration**: DRIIV will leverage its S&T ecosystem to bring in expertise and technologies to protect and restore Yamuna's catchment area by preserving natural habitats, reforesting degraded lands sustainable land use and soil and water conservation practices to minimize soil erosion and sedimentation.

- **Rainwater harvesting and runoff management**: Management of rainwater runoff, rejuvenation of waterbodies, streambank erosion control measures can reduce the influx of pollutants from urban areas, agricultural lands, and construction sites. Depending on the aquifer conditions, managed aquifer recharge need to be implemented.

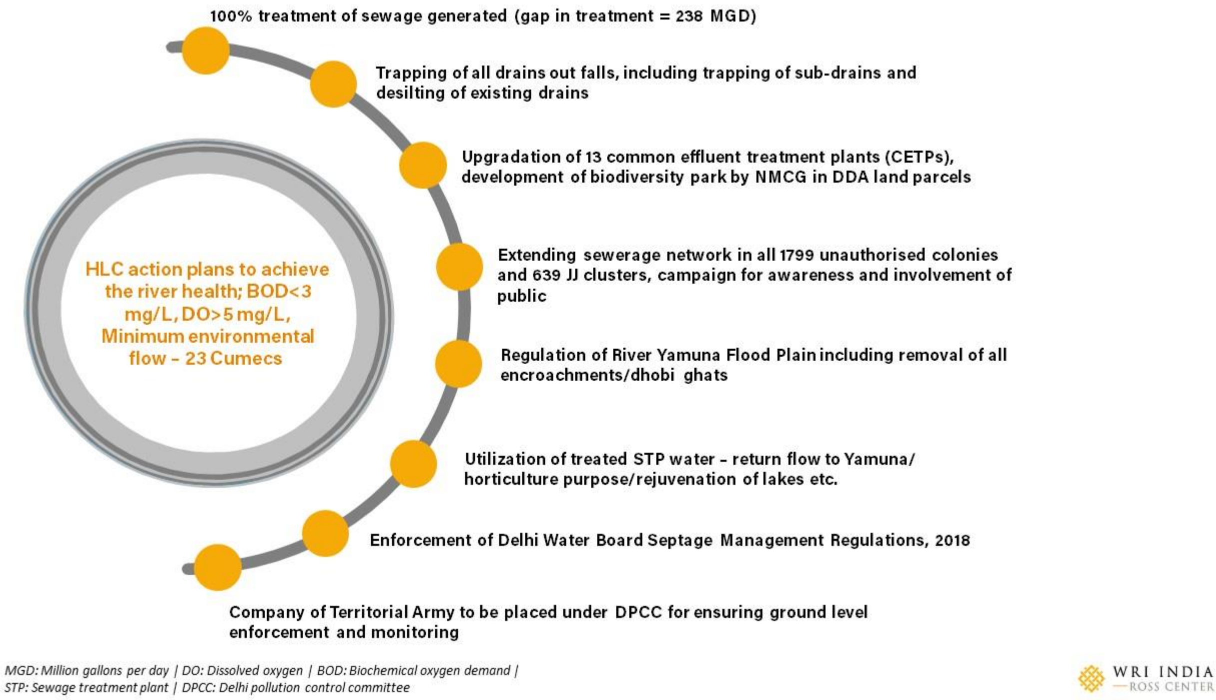
- **Connection with relevant experts**: The Cluster will carry forward the legacy of successful implementation of relevant sustainable technologies in following the examples of other cities for potential cleaning of Yamuna in the Delhi stretch after being connected with the experts suggested by the esteemed participants of the session.
- **Policy advocacy**: Based on the based on the perspectives shared by the key players, policy recommendations will be put forward to rejuvenate the basin, enforce stringent regulations to control industrial pollution, sewage discharge, and waste management practices.
- **Ensuring long-term sustainable outcomes**: Development of a long-term plan for Yamuna restoration with clear goals, targets, and timelines. Establish monitoring and evaluation mechanisms to track progress, assess the effectiveness of interventions, and adapt strategies as needed.

3.2 Recommended expert committee

1. Dr. P. S. Brahmanand, WTC, IARI
2. Dr. (Mrs.) Susama Sudhishri, WTC, IARI
3. Dr. Khajanchi Lal, WTC, IARI
4. Dr. Pawan Labhsetwar, CSIR-NEERI
5. Dr. Paras Pujari, CSIR-NEERI
6. Dr. Girish Pophali, CSIR-NEERI

4. Proposed plan for Yamuna rejuvenation (22km Delhi stretch)

Given the unique governance structure and jurisdictions of National and state government in NCT Delhi, collaborative action plans (kindly refer below) with multiple departments requires a comprehensive approach to restore the river's health and ensure sustainable management, as also recommended in a report by WRI India on the topic. Below are some key recommendations/actions, based on that report.



As per a report by WRI, India, revitalizing the Yamuna in Delhi not only requires a substantial investment and a multi-pronged effort from coordinating agencies across various govt. levels. Streamlining and synergizing actions and mandates of participating agencies will be key for implementing the action plans laid out by the high-level committee (HLC). [*Advancing an Ecosystem-based Approach for Yamuna River Management*, April 2024]

Action plans by DJB (2016)

- Cleaning 3 major drains Najafgarh, Supplementary & Shahdara- **Interceptor Sewer Project;** cleaning all tributary drains of Najafgarh, Supplementary & Shahdara drain – [NGT Order-Setting up of decentralized sewage treatment plants and allied works]

To stop the pollution of the river from the stormwater outfalls and industrial effluents, an **integrated storm water and sewage system with interceptor sewers** has been implemented for **Sabarmati River**. Likewise, an **interceptor sewer project** is underway by DJB at the cost of Rs 2454 crore to tap minor drains discharging sewage into 3 of Delhi's largest drains (**Najafgarh, Supplementary and Shahdara**). Interceptor lines are being installed to capture various sewage discharge points and routing the sewage to new pumping stations on the reclaimed banks. The untreated sewage can then be transported to augmented STPs. There are other parallel and mandatory efforts required to make interceptors work including augmentation of existing capacity of STPs at mouth of Delhi gate and Sen Nursing Home drains, rehabilitation of two major trunk sewers to intercept 13 drains out falling into the Yamuna and most importantly construction of new sewage treatment plants (STPs) after achieving full utilization of existing ones. Additionally, new drain mouths are being identified since the inception of this project, posing challenges to the successful execution of the project.

- Trapping/ cleaning of remaining 15 drains directly falling into River Yamuna- Bela Road, Ring Road sewer Project
- Dredging of major drains and **22 Km** stretch of Yamuna bed
- Laying of sewerage system in unsewered areas- Master Plan 2031.
- Rehabilitation & up-gradation of old sewerage infrastructure- Yamuna Action Plan- III
- Immediate action for Bioremediation & development of public space along all three major drains

4.1 Proposed roadmap for overall environmental improvement of the Yamuna (22km Delhi stretch): -

4.1.1. Monitoring of Yamuna pollution load

The water quality of the Yamuna River, especially in the Delhi stretch, is closely monitored due to its high levels of pollution. Various agencies, including the Central Pollution Control Board (CPCB) and the Delhi Pollution Control Committee (DPCC), are involved in monitoring and managing the water quality (e.g., Automatic Water Quality Monitoring Stations, remote sensing and GIS etc).

DRIIV, operating as a premier network of S&T excellence is well poised to scout for available cutting-edge monitoring approaches and data interpretation techniques that could potentially benefit Yamuna management and helping the concerned authorities addressing some of the challenges faced by the existing systems (like, sensor durability, data accuracy due to calibration issues, infrastructural constraints, complex pollution composition etc). These include nutrient speciation analysis, load apportionment modelling, use of pollution marker compounds, high frequency water quality monitoring etc.

NMCG has implemented IoT-based real-time water quality monitoring systems along the Ganga River. For real-time water quality monitoring of Yamuna, 22 online monitoring stations (OLMS) are likely to be installed by the year-end, as per DPCC. Complementing with this effort, the following approaches already **adopted for Ganga** (under NMCG) can be replicated for high through-put monitoring:

- **Aerial Surveillance** (drones equipped with high-resolution cameras and sensors)

- **Hyperspectral Imaging** (by ISRO)
- Integration of remote sensing and satellite data with ground-based observations under **National Water Quality Monitoring Program**
- **eDNA Analysis**

By adopting these cutting-edge techniques and replicating the success story of Ganga river cleaning efforts, CPCB and other relevant authorities can improve the accuracy and efficiency of water quality monitoring efforts, ultimately contributing to more effective Yamuna management and conservation strategies. A thorough data monitoring study will reveal clear insights on how to protect Yamuna and improve the water quality. The exact sources of nutrient pollution, interception of the raw sewage discharges and their treatment in sub-catchment areas, stricter regulations and increased monitoring of the effluents being discharged from industries, and a system of pollution consents and/or fines need to be implemented.

4.1.2. Sewage treatment

Existing scenario

Delhi has several STPs, including large ones at Okhla, Rithala, Kondli, and Keshopur, among others. These plants are designed to treat millions of liters of sewage daily. The total installed capacity of Delhi's STPs is around 2,400 million liters per day (MLD), but actual utilization often falls short due to various operational issues. 13 CETPs treat wastewater from industrial clusters. The sewage generation, at present, is estimated to be around 792 MGD and treatment is around 550 MGD only (Economic Survey of Delhi, 2023-24). This huge gap between the sewage generated and the sewage treated is due to various challenges like operational inefficiencies, infrastructure and connectivity, pollution load etc. The Hybrid Annuity Model (**HAM**) initiative of DJB has been introduced to address the city's sewage treatment challenges by involving private players in the development, operation, and maintenance of STPs. However, it also suffers from operational challenges, regulatory and compliance issues, technical limitations, and integration challenges with existing infrastructure. Addressing these gaps requires a multi-pronged approach involving upgrading existing facilities, expanding sewage networks, rehabilitation of silted and settled Trunk Sewer Lines, improving operational efficiencies, and ensuring better coordination and funding. While recent initiatives (YAP I, II, III, NMGP), show promise, sustained effort and effective implementation are crucial for achieving substantial improvements in the water quality of the Yamuna River.

A combination of technologies, at all levels must be used together with knowledge of urban habits to help rejuvenate the Yamuna. An ideal and critical aspect for river treatment is decentralisation, i.e. to move away from the riverfront, further upstream, where the waste is first produced. On-site wastewater management is a sustainable and cost-effective solution. Decentralisation calls for changes in urban planning and architecture, and strengthening urban environmental laws for housing societies, gated communities and commercial establishments to treat, recycle and reuse wastewater.

DRIIV, as an S&T Cluster can play a pivotal role facilitating adoption of a combination of natural and advanced technologies to ensure techno-economic and sustainable solutions addressing the gaps in Delhi's sewage treatment.

4.1.2a Decentralized Sewage Treatment Systems, a sustainable alternative

The major STPs in Delhi are based on Sequencing Batch Reactor (SBR), Activated Sludge Process (ASP), and Upflow Anaerobic Sludge Blanket (UASB). As per Central Public Health and Environmental Engineering Organisation (**CPHEEO**, 2012), use of **UASB** for sewage treatment shall be discouraged. While these centralized STPs are essential for managing Delhi's wastewater, complementary decentralized systems can also play a significant role in improving the city's sewage treatment capabilities. DRIIV proposes setting up decentralized STPs based on **natural** (phytoremediation and other biological processes) **and/or compact systems** (physico-chemical and enhanced biological processes through electro-mechanical appliances) to treat sewage locally, reducing the burden on centralized systems and minimizing environmental impact. Possibilities of mechanical rackers for desilting of drains also need to be explored.

1. **Natural systems:**
   - **Phycoremediation:** Developed by **Trinity International**, utilizes a consortium of microalgal species to treat sewage sludge. It can be effectively integrated in the existing STPs after the primary clarification stage.
   - **Root Zone Treatment:** Uses plants and their root zones to treat wastewater. Common plants include Canna, Phragmites, and Typha. **Jalopchar**, developed by IARI is well suited for this purpose.
   - **Vertical Flow Constructed Wetlands:** Developed by ICRISAT, mimic natural wetlands where plants, soil, and microorganisms treat wastewater.
   - **Phytorid Technology:** Developed by NEERI, involves the use of specific plants and bacteria.

Examples of implementation:

- **Nagpur**: Sludge management and greenbelt development through decentralised STP ($100m^3$/day)
- **Auroville, Tamil Nadu:** Implemented various natural STPs using root zone and constructed wetland technologies.
- **Jalgaon, Maharashtra:** A phytorid-based treatment plant treating wastewater for reuse.
- **Art of Living International Center, Bengaluru:** Uses constructed wetlands and root zone technologies for treating its wastewater.

2. **Compact systems:** Designed to treat wastewater locally in small-scale installations, offering efficient and space-saving solutions for urban areas.
   - **Submerged Aerobic Fixed Film Reactor (SAFF)**: Uses fixed film media submerged in an aeration tank, where microorganisms grow and degrade organic pollutants.
   - **Improved Moving Bed Biofilm Reactor (MBBR):** Uses floating plastic media to support biofilm growth, enhancing treatment efficiency in a compact footprint.
   - **Submerged Aerobic Fixed Film Reactor (SAFF) followed by constructed wetland**

Examples of implementation:

- **Maharashtra (MIDC), Chennai (CPCL)**: use SAFF
- **Narmada Nagar**, **MP**: SAFF and constructed wetland
- **Bangalore** (BWSSB): MBBR-based STPs in various locations
- DLF Cyber City, **Gurgaon**: MBBR-based STPs. The compact and efficient treatment systems help meet the high demand for water reuse in cooling tower and landscaping

4.1.3. Reduction in erosion, flood and riverfront development

In addition to mixing of partially treated/untreated sewage in the river through the drains and tributaries, other sources contributing to the pollution load are (i) runoff from the catchment that is loaded with suspended silt particles, (ii) river/stream bank erosion and sliding of soil in slope of bank due to saturation.

Some technologies from the Cluster are proposed below, however, the technologies are location specific and topo-sequence mapping is crucial prior implementation.

1. **Reduction of runoff velocity and suspended load in streams/river:** Catchment treatment from higher slope to lower slope using bio-engineering (includes vegetative: grasses i.e. vetiver, lemon, saccharum spp., para, typha etc.) and engineering measures (trench-cum bund, contour bund/graded/bund/side bund/marginal bunds). Strengthening the bunds of the agricultural land along with agroforestry system (silvi-pasture, slivi-horti-pasture, horti-pasture, silvi-agri or horti-agri) is also crucial.

2. **Riverbank/stream bank erosion control and slope stabilization:**

- Dense plantations of 20-40m width following Miyawaki model in form of silvi-pasture or horti-pasture along the riverbank. Pasture may be simple grasses which will bind the soil or fodder also.
- In riverbank towards lower slope, different retards/spurs/jettys may be constructed. The dimension depends on the meandering shape and flow velocity at that point.
- In all order streams check dams in series can be constructed.
- Retaining walls which hold back soil and prevent sliding of saturated slopes can be constructed at vulnerable slope areas to provide support and stability. Embankment walls along riverfront in Patna has been constructed to protect.
- **Geotextiles**: permeable fabrics used to stabilize soil and prevent erosion.
- **Zero-budget Natural Farming** has also been promoted in recent years. It includes chemical-free farming to be promoted along the length of the river for pollution free river and doubling farmer’s income”.

3. **Flood plain protection**: At lower slope (flood plain) filtration system/spreading system may be implemented for diverting the flow and reducing the velocity so that silt laden runoff will not pollute the water

4. **Groundwater recharge/reuse:** Existing waterbodies may be rejuvenated for increasing groundwater recharge, erosion and flood management. In-situ bio-engineering measures will enhance the groundwater recharge

5. **Stormwater management:** Delhi's stormwater management system is significantly underdeveloped, leading to severe pollution in the Yamuna River. Aging infrastructure, inadequate drainage capacity, and rapid urbanization have resulted in untreated stormwater runoff being discharged directly into the river. This runoff, laden with pollutants such as trash, chemicals, and sewage, exacerbates the Yamuna's pollution

levels. Additionally, the lack of green infrastructure and encroachment on natural water bodies further reduces the city's ability to manage stormwater effectively. Consequently, the river suffers from high levels of contamination, affecting its ecosystem and the health of the local population.

DJB has plans to recycle treated effluents from its STPs while extending its sewerage network to prevent sewage from entering the stormwater drainage system. The "Report of Sub-committee for Development of National Sustainable Habitat Parameters on Urban Stormwater Management" recommends the following indices to enhance water resource availability:

- **Permeability Index**: Percentage of impervious catchment areas, aiming to restore permeability to pre-development levels through sustainable drainage practices.
- **Waterbodies Rejuvenation Index**: Ratio of the area planned for water body rejuvenation to the total area of water bodies, including encroached ones.
- **Waterbody Vulnerability Index**: Ratio of encroached water body areas to total water body areas at a reference date.
- **Rainwater Harvesting/Artificial Groundwater Recharge Index**: Ratio of stored/harvested rainwater volume to measured rainfall volume, promoting mandatory rainwater harvesting and artificial groundwater recharge.

DRIIV proposes and envisages to contribute to the following interventions for stormwater management to reduce Yamuna pollution:

- **Advanced Sewage Treatment Plants**: Upgrading STPs to include tertiary treatment processes before being discharged into the Yamuna or reused.
- **Decentralized Wastewater Treatment**: Implementing small-scale, localized wastewater treatment units in areas not covered by the central sewerage system to prevent untreated sewage from entering stormwater drains.
- **Green Infrastructure**: Implementing green roofs, rain gardens, bioswales, and permeable pavements to enhance natural infiltration, reduce surface runoff, and filter pollutants. Feasibility of **Sponge City Concept** as mentioned in the NMCG Guidelines needs to be checked.
- **Real-Time Monitoring Systems**: Deploying sensors and IoT devices to monitor water quality and flow in real-time, allowing for prompt identification and mitigation of pollution sources.
- **Constructed Wetlands**: Establishing artificial wetlands to treat stormwater through natural processes involving vegetation and soil, which can effectively remove contaminants.

- **Rainwater Harvesting Systems**: Installing systems to capture and store rainwater from rooftops and other surfaces, reducing runoff and supplementing water supply for non-potable uses.
- **Urban Waterbodies Rejuvenation**: Reviving and maintaining natural and artificial waterbodies to improve their capacity to act as stormwater sinks and enhance groundwater recharge.
- **Pollution Control Devices**: Using devices like oil-water separators, sediment traps, and litter booms in stormwater drains to remove debris, oil, and sediments before water enters the Yamuna.
- **Smart Drainage Systems**: Developing intelligent drainage systems that can dynamically control water flow, store excess stormwater, and release it gradually to prevent flooding and reduce pollution loads.

4.1.4. River cleaning

NMCG has recommended comprehensive river surface cleaning by removing floating/submerged debris, which significantly contributes to the river's pollution.

Current Status

The deployment of trash skimmers and manual cleaning teams has been initiated. Regular cleaning schedules are maintained to keep the river surface free from floating debris.

Challenges

- Continuous Inflow of Waste
- Maintenance and Funding
- Public Cooperation

Advanced technological interventions:

- **DrainMaster:** A self-propelled amphibious excavator technology for cleaning and desilting of river water/open drains.

  Implementation example

  A pilot project DM800, in collaboration with MCD and Waste to Wealth Mission of Office of PSA to the GoI was executed in Barapullah drain for a year. The unit could successfully clean and desilt approximately a 3 km stretch of the Barapullah drain starting from Sundial Park to Jangpura, removing approximately 3000 tons of waste in the process.

- **Alphamers:** AlphaMERS has developed 'Tandem Sweeping System' using two shallow drafted waterjet propelled boats. This sweeps a wide swath of 10 Meters between them in one sweep and operates along edge of the lake in shallow drafts.

  Implementation example

  AlphaMERS has installed its proprietary technology of floating trash barrier in nine Indian cities i.e **Gorakhpur, Hyderabad, Bengaluru, Mysore, Coimbatore, Puducherry, Chennai, Thanjavur and Tuticorin**. AlphaMERS has deployed almost 3500 Meters of this barrier and the first installation was a pilot project in Bengaluru and Chennai in 2015 and 2016. The first commercial deployment in 2017 arrested 22000 Tons of trash including 2200 Tons of plastics.

- **WasteShark**: An innovative aquatic drone designed from Netherlands to tackle water pollution by removing floating waste from water bodies. **DRIIV** can facilitate technology transfer and pilot projects.

  Proposed implementation strategies:

  - The Delhi government has employed **trash skimmers** to clean floating waste from the Yamuna. These skimmers collect floating debris, much like the WasteShark, though on a larger scale. However, certain areas of the river are difficult to access due to narrow passages, shallow waters, or dense vegetation, limiting the reach of trash skimmers. The WasteShark can complement these efforts by targeting smaller, hard-to-reach areas and providing data collection capabilities.
  - **Floating booms** have been deployed in the Ganges River to trap floating waste. These passive barriers concentrate debris for easier removal. The challenge is when Floating booms trap large amounts of debris, this accumulation can sometimes exceed the capacity of the booms, leading to overflow and inefficiency. WasteShark can work in tandem with floating booms, in cleaning Yamuna, collecting waste that accumulates around these barriers and providing continuous cleaning.

- **Clearbot**: AI enabled advanced technology to autonomously collect floating debris from water bodies addressing surface water pollution.

  Implementation examples:

- Removal of 600kg to 700kg of waste from a local lake in Shillong within three days.
- Tested in Mumbai's Mithi River, which faces significant pollution challenges due to urban runoff and industrial waste.

4.2 Way forward for a 'clean Yamuna' with a holistic approach

Any technology is as good as its mechanism and the strategy of its implementation. Therefore, before implementing any technology, it is foremost important, that its mechanism of action, regulatory structure, and roles and responsibilities be well understood and defined. Requirements of space, power, treatment time and scope of pollutants removal are other parameters that need to be considered before implementing any technology.

A Detailed Project Report (DPR), outlining the existing problems, scope of work, and desired end results should be drafted. The DPR should detail on the different possible technologies that can be implemented along with the advantages and limitations of each. In addition, it should also include the sustainability quotient of the technology and its relevance in future when the volume of discharge/effluent may increase. All the discharge points of drains should be well marked and identified. The volume of effluent, characteristics of the wastewater, in terms of COD, BOD, nitrates, Phosphates, Coliforms, pH, odour, color etc. are the preliminary data that should be measured and monitored.

In addition, decentralised wastewater models can become relevant and competitive only if we adopt business solutions. The profits from recirculation need to be visible and enticing, along with environmental gains that are publicised. The consequent earnings from the social enterprise could also encourage more people to participate in this and other similar urban greening exercises. In future, all community housing should be required to have decentralised wastewater treatment systems.

And when a wastewater treatment turns into revenue-generating activity, the business model acquires market characteristics, business principles and values. New entrepreneurs need to step into such economically viable businesses, serve the public interest and safeguard our shared environment. The ultimate outcome of adopting decentralised solutions will be better access to environmental justice at the grassroots. Currently, the law as it pertains to waste management remains mostly invisible to the people and becomes prominent only after any litigants have reached the green tribunal. If legal services and support could become available at the local level, they could help improve public health for low-income communities, mitigate groundwater contamination and eliminate the illegal occupation of small water bodies.

5. Appendix

Appendix A: Existing schemes

Govt. initiatives to clean Yamuna

Several government schemes have been implemented to address the issue of cleaning the Yamuna River in Delhi:

- **Yamuna Action Plan (YAP)**: Launched by the Government of India in 1993, this plan aimed to reduce pollution in the Yamuna River by treating sewage and industrial effluents. It has undergone multiple phases of implementation.
- **National Mission for Clean Ganga (NMCG)**: While primarily focused on the Ganges River, NMCG also includes efforts to clean the Yamuna. It implements various projects and initiatives to improve water quality and biodiversity along the river.
- **DJB initiatives**: DJB has undertaken various projects to treat sewage and reduce pollution in the Yamuna.
- As per **National Green Tribunal** (NGT) directives, the govt. of NCT Delhi in coordination with Delhi Development Authority (DDA), Delhi Pollution Control Committee (DPCC), DJB and the State Governments of Haryana and Uttar Pradesh is pursuing the action to set up the requisite STPs and implement the action plan for prevention and control of pollution in Yamuna.

Key Funding allocated for Yamuna

- **YAP**: multiple phases of YAP have received funding from the central government, eg., YAP Phase III was approved with an estimated cost of over ₹1,656 crore.
- **Namami Gange Programme** (NGP): A total expenditure of ₹ 1672.49 crore has been made in the 23 projects for river Yamuna
- **Rejuvenating Najafgarh drain**: Allocation of ₹705 crore (2022-23), project costs over ₹2000 crore
- **DJB Projects**: DJB receives funding from both the central and state governments for projects related to water supply, sewage treatment, and river cleaning. Significant amounts have been allocated for constructing and upgrading sewage treatment plants (STPs) and interception and diversion projects along the Yamuna.
- **Bio-Remediation Projects**: Funding is allocated for implementing bio-remediation techniques to improve water quality along the Yamuna's banks.

Appendix B: Existing technologies (based on success stories)

A number of novel and nature-based strategies, which are technologically advanced and economically feasible can also be implemented for rejuvenation of river Yamuna and restoration of its original glory.

Drain Master DM800: The Drain Master DM-80, designed and developed by Cleantec Infra Pvt. Ltd., Mumbai, addresses the challenge of cleaning congested urban drains clogged with mixed waste, including construction and demolition debris. This self-propelled, transportable, and amphibious excavator is equipped with multipurpose attachments, capable of removing 50-100 m^3 of waste per day. The DM-80 was deployed to clean and desilt approximately a 3 km stretch of the Barapullah drain in South Delhi under the Waste to Wealth Mission. Over one year, it successfully removed around 3000 tons of waste, significantly mitigating foul odor, vector-borne diseases, and flooding. This innovative technology fills a critical gap in urban drain cleaning, offering an effective solution where traditional equipment fails due to limited access and narrow passages.

https://www.investindia.gov.in/team-india-blogs/success-one-year-pilot-project-drain-master-dm-80

AlphaMERS: AlphaMERS Ltd is at the forefront of innovative solutions for the marine environment, focusing on lake and river cleanup, ocean energy, and oil spill response. Their Tandem Sweeping System, utilizing shallow drafted waterjet propelled boats, effectively clears large swaths of water bodies without being fouled by aquatic biota. Their floating trash barriers (FTBs) have been installed in nine Indian cities, capturing thousands of tons of trash and restoring water bodies to their pristine state. AlphaMERS has also developed floating wetlands, which use hydroponic plants to clean polluted water. For oil spill response, AlphaMERS provides essential equipment such as Single Point Inflation Oil Booms and boom reels, along with on-site resources for major oil companies and ports. Additionally, their ocean energy solutions include a wave energy converter (WEC) and a wave-powered boat prototype, harnessing renewable energy from sea waves. Through these innovative technologies, AlphaMERS Ltd is dedicated to mitigating, conserving, and managing aquatic environments, contributing significantly to India's sustainable development.

https://alphamers.com/

Phycoremediation: This method involves using a consortium of microalgal species to remove pollutants from wastewater, improving its quality before discharge. It offers several advantages, such as efficient nutrient removal for COD and BOD reduction, low energy requirements and operation costs, and the potential for biomass production. By carefully tailoring to the specific needs and conditions of the site and wastewater being treated, Phycoremediation technology can be implemented as an environmentally friendly and sustainable approach to treating drain wastewater. Trinity International have carried out a number of pilot scale projects to demonstrate the efficacy of the technology for the treatment of domestic waste as well as industrial discharges. Our project with leather industry, malt processing, and electroplating industrial effluents have conclusively proven that high TDS, TSS, COD and heavy metal content in the effluent can be reduced and brought within CPCB limits. Correspondingly, our work with lakes and pond rejuvenation have shown convincing results in removal of BOD/COD, odour, coliforms (total and faecal), nitrates (total and ammoniacal) and phosphates from the waterbody. Phycoremediation has also shown substantial results in the treatment of MSW leachate, which otherwise is practically untreatable by conventional technologies. In conclusion, phycoremediation can comprehensively treat municipal as well as industrial wastewater discharges in a nature-friendly, economic and reliable approach.

Nanobubbles: Rapid digestion of sludge in the river due to prolonged deposition by untreated drains is advanced oxidation via nanobubbles. These nano-bubbles have very high oxygen transfer rates (OTR) that make them particularly effective at improving water quality, enhancing water treatment processes other than improving productivity in industrial and agricultural applications.

Nanobubble technology can also be conjoined with phycoremediation for more effective treatment of effluents across all parameters.

WasteShark: developed in Rotterdam, Netherlands, is an innovative aquatic drone designed to tackle water pollution by removing floating waste from water bodies. Inspired by the natural feeding behavior of a whale shark, this autonomous device efficiently skims the surface, collecting plastic, algae, and other debris before they can cause further environmental damage. The WasteShark not only cleans the water but also gathers valuable data on water quality, contributing to broader conservation efforts. Its design is compact and environmentally friendly, making it a sustainable solution for urban waterways and harbors worldwide.

https://dronesolutionservices.com/wasteshark-1

Clearbot: Clearbot is an advanced autonomous marine debris cleaner designed to tackle water pollution in various aquatic environments, developed in Hong Kong. Powered by solar energy, Clearbot navigates water bodies independently, using artificial intelligence and computer vision to detect and collect floating debris efficiently. It operates silently and without emissions, making it environmentally friendly. Clearbot's ability to gather real-time data on water quality and waste composition enhances environmental monitoring efforts, contributing to cleaner waterways and promoting sustainable conservation practices globally.

Appendix C: Important resources

- Environmental Impact Assessment (EIA) 2016
- Hazardous waste management rules by CPCB

(https://cpcb.nic.in/rules/)

- Compendium for sewage treatment technologies

(https://nmcg.nic.in/writereaddata/fileupload/15_Technologies%20Involved.pdf)

- Compendium of River Management Plans

(https://www.nmcg.nic.in/writereaddata/fileupload/5_Compendium%20of%20River%20Management%20Plans.pdf)