OFFICE OF THE YAMUNA POLLUTION MONITORING COMMITTEE
APPOINTED BY HON'BLE NGT
ROOM NO. 58, INDIA INTERNATIONAL CENTRE
40, MAX MUELLER MARG, LODHI ESTATE
NEW DELHI – 110003

No. YPMC/2020/421 Date: 17.2.2020

Ld. Registrar General,
Hon'ble National Green Tribunal,
Faridkot House, Copernicus Marg,
DELHI

Subject: Comments of Yamuna Monitoring Committee on the Report of CPCB on Phyto-remediation /Bio-remediation in drains.

Dear Sir,

In compliance of the order dated 11.9.19 in OA no. 06.2012 –Manoj Mishra vs UOI and Ors, the Yamuna Monitoring Committee submitted its Special Report on Bio/Phyto Remediation of waste water in drains to the Hon'ble Tribunal on 20.1.2020.

After considering the above report of the YMC, the Hon'ble Tribunal vide its order dated 22.1.2020 directed the CPCB to prepare a report on Bio / Phyto-remediation in drains and submit it to the YMC by 07.02.2020. The YMC was asked to submit the report along with its comments to the Hon'ble Tribunal before 18.2.2020, the next date fixed for hearing.

Accordingly, the Report received from CPCB on 11.2.2020 along with the Comments of YMC are enclosed herewith, with a request that these be placed before the Hon'ble Bench of the Tribunal.

Yours faithfully,

Shailaja Chandra,
Member,
Monitoring Committee for Yamuna

B.S. Sajwan,
Member,
Monitoring Committee for Yamuna

Encl: As above.

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COMMENTS OF THE YAMUNA MONITORING COMMITTEE ON THE CPCB REPORT ON ALTERNATIVE TECHNOLOGIES FOR MANAGEMENT OF WASTE WATER IN DRAINS

Shailaja Chandra
B.S. Sajwan
Members of Yamuna Monitoring Committee

Appointed by the
Hon'ble National Green Tribunal
Vide order Dated 26th July 2018

Dated 17th February, 2020.

CPCB REPORT ON ALTERNATIVE TECHNOLOGIES FOR MANAGEMENT OF WASTE WATER IN DRAINS-COMMENTS OF THE YAMUNA MONITORING COMMITTEE

Management of Septage in Urban areas.

In many cities in India the disposal of sewage remains one of the biggest challenges besetting the Urban Local Bodies (ULBs).The National Policy on Faecal Sludge and Septage Management (FSSM) was notified in February 2017 by the Ministry of Housing & Urban Development. The policy recognises that urban households do not understand the utility of a septic tank as a requisite pre-treatment unit. They mostly build large containment tanks which overflow into the drains. The overflow is often connected to available open drains instead of a proper soak pit.

https://smartnet.niua.org/sites/default/files/resources/FSSM%20Policy%20Report_23%20Feb_Artwork.pdf

The National Septage Management policy recognised that weak sanitation had significant health costs and untreated faecal sludge and septage from cities is the single biggest source of water pollution in India. Human waste has clearly been identified as the leading cause of such water pollution causing a host of diseases including diarrhoea, agricultural-produce contamination and environmental degradation. The National FSSM policy expressly refers only to on-site sanitation facilities and distinguishes its approach from conventional sewerage systems. The State Governments, ULBs, and relevant public and private utilities were asked to take necessary steps to ensure that the Policy covered all the projects, programs and schemes related to provision of onsite sanitation services of every organisation, irrespective of the source(s) of funding. The State Governments were required to prioritize funding to implement the FSSM plan at city-wise level and encourage the ULBs to levy sanitation tax/ user charges to meet the O&M costs. They were also asked to facilitate private sector participation “through an easy and amenable PPP relationship framework, to ensure adequate financing and sustainability of FSSM projects”. Progress on the implementation of the FSSM policy is not the subject of this note but two points are noteworthy: first, the management of Septage and faecal sludge was recognized as separate from conventional projects for sewage conveyance and treatment requiring an independent policy. Second, that National policy does not contain any mention of phyto-remediation as a means of treating sewage from unsewered areas in a decentralised manner. The State of Uttar Pradesh has, however, prepared an ambitious proposal and sought funding to the tune of some Rs 1800/- crores to execute bio/phyto-remediation projects only subject to receiving funds from NMCG. The progress is not known to YMC.

Management of Sewage in Urban areas Need for Alternative Technologies

The Hon'ble NGT has taken note of the fact that the management of sewage, faecal sludge and its conveyance is very poor. It has directed the ULBs in Delhi to stop the discharge of sewage into storm water drains. Recognizing the long lead time and uncertainties about land allotment, formulation of DPRs, appointment of consultants, award of work and delay in execution the NGT had considered several options suggested by experts to introduce alternative technologies to contain the sewage which ultimately pollutes the River and its tributaries. In its order dated 11.9.19 in OA no. 6/2012-Manoj Mishra vs UOI and ors NGT inter alia directed as under:

"Bioremediation and/or phyto-remediation or any other remediation measures may start as an interim measure positively from 01.11.2019, failing which the State may be liable to pay compensation of Rs. 5 Lakhs per month per drain to be deposited with the CPCB. This however, is not to be taken as an excuse to delay the installation of STPs. For delay of the work, the Chief Secretary must identify the officers responsible and assign specific responsibilities. Wherever there are violations, adverse entries in the ACRs must be made in respect of such identified officers. For delay in setting up of STPs and sewerage network beyond prescribed timelines, State may be liable to pay Rs. 10 Lakhs per month per STP and its network. It will be open to the State to recover the said amount from the erring officers/contractors. With regard to works under construction, after 01.07.2020, direction for payment of environmental compensation of Rs. 10 lakhs per month to CPCB for discharging untreated sewage in any drain connected to river Ganga or its tributaries and Rs. 10 lakhs per month to CPCB per incomplete STP and its sewerage network will apply. Further with regard to the sectors where STP and sewerage network works have not yet started, the State has to pay an Environmental Compensation of Rs. 10 lakhs per month after 31.12.2020. The NMCG will also be equally liable for its failure to the extent of 50% of the amount to be paid. Till such compliance, bioremediation or any other appropriate interim measure may start from 01.11.2019."

Subsequently, a meeting was held in the Conference hall of the Tribunal on 3.1.2020 wherein it was reiterated that bio-remediation/phyto-remediation must be pursued as an interim measure till the STPs were established. This was because the continuing discharge of large quantities of sewage into the drains and ultimately the rivers was unacceptable. The Yamuna Monitoring Committee (YMC) was directed in consultation with the CPCB, DPCC, NEERI, CEMDE, INTACH and other experts from DJB and IFCD to suggest workable methodologies for Bio/Phyto-remediation to the Tribunal. YMC placed a brief report before the Tribunal on 20.1.20 and the Bench in an order dated 22.1.2020 directed as under:

"Since the above report does not mention the generic and representative models which could be customized, adapted and adopted to the natural scenario including the drains in question, let CPCB furnish such a report containing at least ten generic and representative models which are techno-economically feasible and can be implemented after customization to the YMC by 07.02.2020 and the YMC may include the report with its comments in its report to be submitted to this Tribunal before the next date by e-mail at judicial-ngt@gov.in. CPCB furnish a report in terms of Para 25 above to the YMC by 07.02.2020 and the YMC may include the report with its comments in its report to be submitted to this Tribunal before the next date by e-mail at judicial-ngt@gov.in."

Pursuant to the above directions CPCB has prepared detailed guide lines which contain various technological options available for in-situ and ex-situ treatment of waste water in the drains under the overall umbrella of bio-remediation/phyto-remediation. The YMC received the report prepared by CPCB on 11.2.2020 (copy attached)and the comments follow.

General Comments of YMC on the CPCB Report dated 11.2.2020

The Report of CPCB is divided into 8 segments and apart from recounting the advantages of biological treatment of waste water using alternative technologies it provides the criteria for selection of different technologies/ models together with the challenges which would have to be confronted in adopting each model. Some case studies have been referred to also.

The CPCB report has been prepared after multiple rounds of consultation with NEEERI, TERI, Jamia Milia, IIT Roorkee, IIT BHU and other knowledgeable agencies. The positive features alluded to include factors like low cost, high efficiency in reducing the BOD load, reduction in heavy metals and coli form, and aesthetic appeal apart from providing various ecosystem services like ground water recharge, bio-diversity conservation, habitat for birds etc. The model-wise contours of drains and their tributaries designated as 1st, 2nd and 3rd order drains have also been provided.

The technologies have been described in the report and are not being repeated here. Only those aspects are being highlighted which in the opinion of the YMC show comparative advantage from the point of view of treating large quantities of sewage emanating from areas which have habitation and are contributing in large measure to the pollution load in the rivers.

The models suggested by CPCB take into account the drain profile, the flow, the width, depth and pollution load in the drain, and the presence of both organic and industrial waste in the drains. The permutations and combinations vary between drains with flows ranging from less than 20 MLD to more than 100 MLD. The drain widths covered under different models vary from less than 3 metres to more than 15 metres. The pollution load in BOD terms ranges from less than 50 mg/L to more than 100 mg/L. Most storm water drains and their feeder drains will fall under one or the other category/models given in the CPCB report. The range of situations discussed appears to cover the universe of situations prevailing in most drains in the river basins.

Points Worth Highlighting

1. The models cover situations involving both in- situ drain treatment if no land is available adjacent to the drain and situations where land may be available on either side of the drain for ex-situ treatment. The Report highlights the criteria for selection of situation specific technologies and also provides Standard Operating Procedures where required. Aspects like benchmarks for power consumption, efficiency norms, the de-sludging / dredging schedule, the need to increase the number of modular units in case of more than a 20 MLD flow, preventing entry of untreated sewage between the inlet and outlet points of the treatment area have all been delineated. The inlet parameters too have been prescribed.
2. A scrutiny of the 15 different models indicates that the main differences lie in the number of Oxidation and waste stabilization ponds as well as Physical treatment units in the Constructed Wetland system. As a rule of thumb, the higher the pollution load and

flow, the higher is the number of units required. With the increase in the width, length and flow the number of units increases. However, a closer look at CPCB's 15 models shows that there is some degree of overlap in the requirements for treatment units of oxidation ponds, facultative ponds and physical treatment units under the CWS (Constructed Wetlands System). The number of models need to be compressed to avoid confusing the field functionaries as except the Public health engineers, there exists little conversance with these technologies functioning in densely inhabited areas.

3. The CPCB report has referred to case studies of CEMDE (Neela Hauz of Prof Babu), NEERI (at Prayag Raj and Gorakhpur) and Deoprayag model of Soil Biotechnology, units at Anupshahar, Vindhyachal (Mirzapur), Fatehgarh (Farrukhabad) and Vaidyabati in West Bengal. **These are isolated examples of alternative technology use being attempted in different states and most are on a very small scale (only a few MLD flow) of less than 10 MLD. These case studies have achieved varying degrees of pollution reduction ranging from as low as 40% to as high as 96%.**
4. The Report has also given an example of a proposed treatment scheme where a first order drain (Using Hacks Stream order) with flow as high as 500 MLD, drain width of 30-90 metres and BOD load of 100-250 mg/L can be treated through a series of CWS containing multiple units of oxidation ponds, physical filters under the CWS with a BOD reduction claimed to be of the order of 50-70%. **This is a futuristic estimation and much will depend on design, size, geographic location and the size of the physical treatment units designed to meet the specificity of each drain. Whether a successful 10 MLD model can be up scaled to 500 ML needs to be answered by experts after examining the specific location.**
5. YMC feels that while the models can serve as generic models for different flow regimes, drain profile and organic load what is required is to draw up site specific designs based on land availability adjacent to the drain, the geographic features of the drains which are selected, the catchment area, the gradient, flow, depth and other related parameters. Whether the drain passes through open stretches of land or through heavily built up areas has to be seen on a case by case basis. The actual design of the oxidation ponds, the physical treatment units, the Gabian structures, their height etc. will have to be site specific which can only be done after survey and study of the drains and site in question.

Specific Comments on Drains and Models

1. Of the 15 Models, 12 models are for both for in- situ and ex- situ drain treatment. Out of the remaining three, two models where the drain width is less than 3 metres and the flow less than 20 MLD, ex-situ treatment has been suggested using vacant land available on the sides of the drain or the catchment area of the drain- generally 3rd order drains. This assumes that land on the sides will be available. In the remaining model where the drain width exceeds 15 metres, both in-situ and ex-situ treatment have been discussed, again presuming availability of land. With the width of the drain being more than 15 metres both in-situ and ex- situ are in any case feasible.

2. As rightly pointed out in the introduction part, the alternative technologies of Bio/Phyto remediation are effective in improving water quality in drains and for further polishing of STP treated water. In the criteria for selection of technologies at S. No. (xvi), however, it has been mentioned that the waste water to be treated through Bio/ Phyto remediation should be of BOD more than 40 mg/L. This will imply that Bio/Phyto-remediation need not be used for polishing the treated waste water of STPs, as treated water may have BOD of as low as 10 mg/L.

3. In the case of Delhi, the models/designs appear to be feasible in some drains under the Department of I&FC and in the 2nd and 3rd order drains in the catchment areas of Najafgarh and Supplementary drains and some parts of Shahdara Drain. But for drains which are emerging from unauthorised (U/A) colonies or passing through them, the water level in the drain and the houses is too small which can cause inundation during storms. Also ponding, as recommended in the Report, will involve putting gravel inside flowing wastewater and will reduce the capacity of the drain. To be prepared for such situations, precautions need to be spelt out and ways to overcome them included in CPCB's advice.

Issues Flagged by YMC

I. The report recognizes certain constraints that will affect the performance which are highlighted here. YMC has also added a few points which stand out and need to be brought on record as they can affect the success of the initiatives.

II. There is large variation in the flow in storm water drains during the monsoon and during the dry season. In Najafgarh drain alone the monsoon discharge is almost four times the discharge during the lean season. Therefore, the structural integrity of the

CWS, physical treatment units and root zone treatment system during the monsoon will have to be safeguarded.

III. The high BOD in excess of 100 mg/L will require periodic de-sludging, and the models/designs will have to cater for such periodic removal of sludge without in any way affecting the normal and continual functioning of the system.

IV. The botanical species used for reducing BOD, COD and heavy metals etc need to be described based on the case studies. Their availability and source need to be included in the report.

V. The representative models have been prepared based on specific case studies, **all of which pertain to drains with flows less than 10 MLD.** The models built by CPCB based on extrapolating such experience for 10 times the size raises some doubts. There is no case study available for drains carrying much higher flow exceeding 100 MLD. Therefore, each model particularly for high levels of flows and high organic load must be designed with greater care and the claims verified before suggesting large scale replication.

VI. YMC understands that the design, number of units, the need for oxidation ponds as well as physical treatment through Gabian (rock and pebble structures and ridges) will fluctuate based on the drain characteristics, flow and pollution load. In the report the pictorial representation of different models is almost identical and applicability in different conditions is not discernible

VII. In the example given at S. No. 9 (page 35) of the Report a drain having width of 30-90 metres, a waste water flow of 500 MLD and an Organic load of 100-250 mg/L has been referred. The report suggests the adoption of an in-situ Constructed Wetland System (CWS) involving two oxidation units of 100 m each and two physical treatment units of 75 m each. These drain parameters are similar to those prevailing in the Najafgarh catchment area. For this drain it is essential that the design and structural aspects are worked out after detailed survey of the catchment profile of the drain and the volume and pollution load therein.

<u>Operational Issues</u>

1. Phyto -remediation is a new area for ULB/ DJB engineers. It would be useful if the implementing agencies are informed about the compatibility of different models for different situations e.g. for a lake receiving waste water, for outfall points where the

drain meets the river, drains abutting urban settlements, drains flowing adjacent to parks and gardens, drains and streams flowing through undulating or hilly terrain where the drains have a high gradient. A correlation between the suggested models and different drains/catchment characteristics will help get a better understanding of the relevance of each model to a given ground situation.

2. At present the ownership of the drains in Delhi lies with multiple agencies like IFCD, DMCs, PWD, DSIIDC and DDA. None of these agencies except IFCD possess the relevant drain data like flow and pollution load in respect of each drain under their charge. Nor do they have any in-house technical expertise on sewage/waste water treatment methodologies and the parameters required to be monitored.
3. On the other hand, DJB possesses the necessary technical and managerial expertise on sewage treatment but does not own or control any of the drains. If alternative technology models are to be tested on the ground, the drain owning agencies will have to be provided exposure to what is needed to be done and the various technological options suggested by the CPCB. Therefore, these agencies will require hand holding to imbibe technology so that the mandate given by the Hon'ble Tribunal is implemented on the ground.
4. The technology developers and providers including the licensees of technology as well as the user agencies will have to be brought on a common platform. This role should legitimately be performed by the DJB who under the Delhi Water Act of 1998 have the responsibility for "Sewage".
5. Unless the linkages and partnerships between the technology users is established, the representative models prepared so diligently by the CPCB may not get implemented. There has to be ownership for control of sewage both short term and long term within DJB irrespective of where it is generated and by whom. Only when this recognition and ownership is present, will DJB be in the driver's seat to propel different agencies to adopt alternative technologies.

Recommendations:

The following recommendations are being made to enable taking this subject forward.

1. The need for bio- remediation of drains that carry sewage is fully recognised. To permit the pollution of the water bodies, the ground water and the Rivers because

of past negligence in establishing sewage systems would be environmentally hazardous particularly as any admixture with drinking water pipes can give rise to water borne diseases like cholera diseases dysentery. That every step has to be taken to prevent such pollution is unquestionable. The effectiveness and relative simplicity and cost-effectiveness of constructed wetland systems as well as several other models of bio/phyto-remediation have been accepted by CPCB and all agencies connected with sewage management. And at an All India level, it is desirable that are the models are shared with the ULBs and an opportunity is given to the stateGovernments to respond. In the first stage CPCB needs to organize a workshop to sensitize all the stakeholders on the alternative technological solutions.

2. NGT may consider giving a direction to the Ministry of UD to notify a supplementary policy containing the guidelines on phyto-remediation as a policy directly addressing decentralised sewage management on the lines of FSSM policy. The Ministry may be asked to have the CPCB Guidelines and Models discussed with the State Departments of Urban Development in the next two months before the policy is adopted and notified. Before that CPCB should hold a meeting with the ULB engineers and PCB Chairmen and Member Secretaries to orient them and also motivate them.
3. In the case of GNCT of Delhi, it may not be necessary to wait for a policy to be notified because the experts are all available locally and all that needs to be done is to select drains where the feasibility and impact in treating sewage would be worthwhile. Directions could be considered to be given to GNCT, the Department of Irrigation and Flood Control, the Delhi Jal Board and the Municipal Corporations and other Urban Local Bodies in UP and Haryana to select drains on the basis of CPCB guidelines. They can associate the DPCC and the State PCBs and complete the selection exercise in two months. A direction could be considered to be given to the Chief Secretary and the Principal Secretary, Urban Development in Delhi, UP and Haryana to get the identification of models vis-a vis the drains polluting the Najafgarh, Shahdara and Supplementary drains started. They can be directed to do the exercise in consultation with CPCB. In the case of the Haryana drains, the Haryana Yamuna Monitoring Committee (HYMC) could be tasked with follow up on a

date to day basis. Under the aegis of the Ministry of Jal Shakti and NMCG, Delhi and and Haryana can give an early start to the drain selection process.

4. The drains as well as models selected can at best be pilots to provide experience. Replication and upscale ability would depend on the outcomes experienced both in terms of selection and implementation as well as the effect on the reduction of pollution. For the sake of abundant caution, the pilot projects should cannot be replicated until experience of planning, execution are known and the outcomes measured. The reason why parallel action is suggested is because in the case of drains out falling into the Yamuna at Delhi there is already considerable knowledge about the topography of the drains, the quantum of sewage, the flow and other determinants. A few pilots covering all the 15 models in different geographic location within Delhi have a better chance of coming up under the direct supervision of the key central government agencies viz M/o Jal Shakti, NMCG, M/o EF&CC and CPCB.
5. The Ministry of New &Renewable Energy (MNRE) had drawn up and notified state wise lists of agencies to install solar panels on turnkey basis maintained on the website of the Ministry centrally but also given freedom to the states to empanel state specific lists of service providers. On similar lines there is a need to start a dialogue with possible agencies who might be interested in taking up turn- key projects and get empanelled with the Governments as was done by MNRE and the State Power Departments to encourage solar rooftop projects. An exercise to generate lists of agencies who are interested in executing turn-key projects should be started in parallel by CPCB under the aegis of the Ministry of E F&CC or Urban Development which can be left to the Government to decide.. An illustrative list of the agencies which have executed the projects mentioned by CPCB in the list of case studies are already available with the CPCB and NMCG and those could be the starting point.

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File No. A-19014/43/06-UPC-I Date: 11/02/2020

To,

The Yamuna Pollution Monitoring Committee
Room No. 58, India International Centre
40, Max Muller Marg, Lodhi Estate
New Delhi-110003

Subject: Submission of Report on Alternative Treatment Technologies for Wastewater treatment of Drain in compliance to directions of Hon'ble NGT

Sir,

I am directed to forward a report on the above mention subject in compliance to Hon'ble NGT order dated 22.01.2020 in the matter of OA No. 06 of 2012 titled; Manoj Mishra Vs Union of India & ors.

Yours faithfully

11/02/20

[A K Vidyarthi]
Divisional Head – WQM-II

Encl.: As above

ALTERNATIVE TREATMENT TECHNOLOGIES FOR WASTEWATER TREATMENT IN DRAINS

In Compliance to Direction of Hon'ble NGT in the Matter of OA No. 06/2012

Titled Manoj Mishra Vs Union of India & ORS

February, 2020

CENTRAL POLLUTION CONTROL BOARD, DELHI

CONTENTS

LIST OF ABBREVIATIONS

BOD- Biological oxygen demand

COD – Chemical oxygen Demand

CPCB – Central Pollution Control Board

CW- Constructed wetland

DO – Dissolved oxygen

EL – Elevation

EM – Electromagnetic

ICT- Institute of Chemical Technology

IIT- Indian Institute of Technology

MLD- Million liter per day

MSL- Mean sea level

N – Nitrogen

NEERI- National Environmental Engineering Research Institute

NGT – National Green Tribunal

NH_3-N – Ammonical Nitrogen

NO_3-N – Nitrate Nitrogen

O&M - Operation & Maintenance

OL- Organic load

OLR – Organic loading rate

P- Phosphorus

PO_4-P – Phosphate

STP – Sewage Treatment plants

TERI- The Energy and Resources Institute

TSS – Total dissolved solids

V – Volume

WSP- Waste stabilization pond

REPORT ON ALTERNATIVE TREATMENT TECHNOLOGIES FOR WASTEWATER TREATMENT OF DRAINS IN COMPLIANCE TO DIRECTION OF HON'BLE NGT IN THE MATTER OF OA NO. 06/2012 TITLED MANOJ MISHRA VS UNION OF INDIA & ORS.

1. BACKGROUND

The verbatim of Hon'ble National Green Tribunal in the matter of OA No. 06 of 2012 titled; Manoj Mishra Vs Union of India & Ors. vide order dated 22.01.2020 at para 25 is as follows:

> *"Since the above report does not mention the generic and representative models which could be customised, adapted and adopted to the natural scenario including the drains in question, let CPCB furnish such a report containing at least ten generic and representative models which are techno-economically feasible and can be implemented after customization to the YMC by 07.02.2020 and the YMC may include the report with its comments in its report to be submitted to this Tribunal before the next date by e-mail at judicial-ngt@gov.in.*
>
> *CPCB furnish a report in terms of Para 25 above to the YMC by 07.02.2020 and the YMC may include the report with its comments in its report to be submitted to this Tribunal before the next date by e-mail at judicial-ngt@gov.in."*

A meeting was convened on 27.01.2020 to consult experts including representatives from NEERI, TERI, Delhi University and other stakeholders. During the meeting, apart from in-situ remediation, low cost decentralised treatment systems (waste stabilization pond, oxidation pond, anaerobic lagoon) were also discussed, which can be adopted as ex-situ treatment. Another meeting was convened on 29.01.2020 wherein consultation was held with experts from IIT-Roorkee, IIT-BHU and ICT - Mumbai.

2. ADVANTAGES AND ECOLOGICAL SERVICES OF ALTERNATIVE BIOLOGICAL TREATMENT TECHNOLOGY

In situ treatment methods such as constructed wetland system, phytoremediation, Eco Bio Block system, microbial bio remediation are most favorable methods for alternative biological treatment technology of drains. Although above treatment systems are temporary provision but it may be adopted for further polishing of STP effluent. Alternative biological treatment technologies are not only useful in improving water quality of drains / rivers but are also helpful in rejuvenation of the ecology of a river system. Benefits of alternative biological treatment technologies are highlighted below:

- Alternative biological treatment technology methods such as phytoremediation or wetland systems are efficient in terms of nutrient removal such as removal of nitrogen and phosphorous.

- All alternative biological treatment technologies are low in energy incentive and not only reduces carbon footprint thereby minimizing climate change impact but also contributes to carbon sequestration.

- Constructed Wetlands have highest microbial diversity that will biodegrade not only organic but all emergent pollutants including odor producing substances & gases, antibiotic, detergent, pharmaceutical products, etc.

- The technologies provide benefits like increase in the biodiversity and biomass production apart from habitat conservation.

- Constructed Wetlands may attract migratory birds, as well as provide aesthetic and recreational services to the public.

- Studies indicate that there is massive reduction in pathogenic microbes in alternative biological treatment technology as compared to conventional treatment.

- In-situ remediation technique does not require much energy, its maintenance cost is relatively low, it is easy to develop, operate and manage as compared to conventional technology. Besides high reduction efficiency of BOD, different alternative treatment technologies are efficient in increasing Dissolve Oxygen (DO) and reducing Fecal Coliform (FC) e.g. Phytoremediation technique can reduce FC by 50% and increase DO from 0 to 5 mg/l; Oxidation Pond can reduce FC by more than 95% and increase DO from 0 to 5mg/l; similarly, lagoons are efficient in reduction of FC by 50-70%.

- The cost of alternative biological treatment technology is extremely low.

- In-situ remediation is more efficient in restoring self-purification system of river and also immobilization of heavy metals.

- Constructed wetlands contribute to groundwater recharge as well as results in buffering of ambient temperature and odor.

3. WATERSHED PATTERN – STREAM ORDER

Based on the drainage pattern, all drains traverse towards recipient water body located downstream of drains. Drains which directly discharge into recipient water bodies such as rivers, rivulets, ponds, lakes etc. are called as first order drain. Drains which join into first order drain are called as second order drains. Similarly, third and fourth order drains could be defined. The first and second order drains which confluence directly with River system are relatively larger with continuous flow.

Generally, drain emerging from urban centers/ rural habitats are third or fourth order drains which confluence into larger second or first order drains finally meeting into river/ pond/lakes.

Third and fourth order drains are rather narrow, very shallow, located at higher gradient, usually shorter in length and often covered / or passed beneath roads. Similarly, due to unplanned growth, untreated sewage/ industrial discharge into such drains, which ultimately meets first and second order drain (Figure – 1).

This sort of order of drain is defined as classic stream order, also called Hack's stream order. Drains usually carry wastewater from Urban/Rural centers called domestic sewage or effluent from Industrial activities and surface runoff including agricultural runoff.

Therefore, drains could be broadly categorized as sewage drains carrying only sewage and mixed drains carrying sewage and industrial effluent.

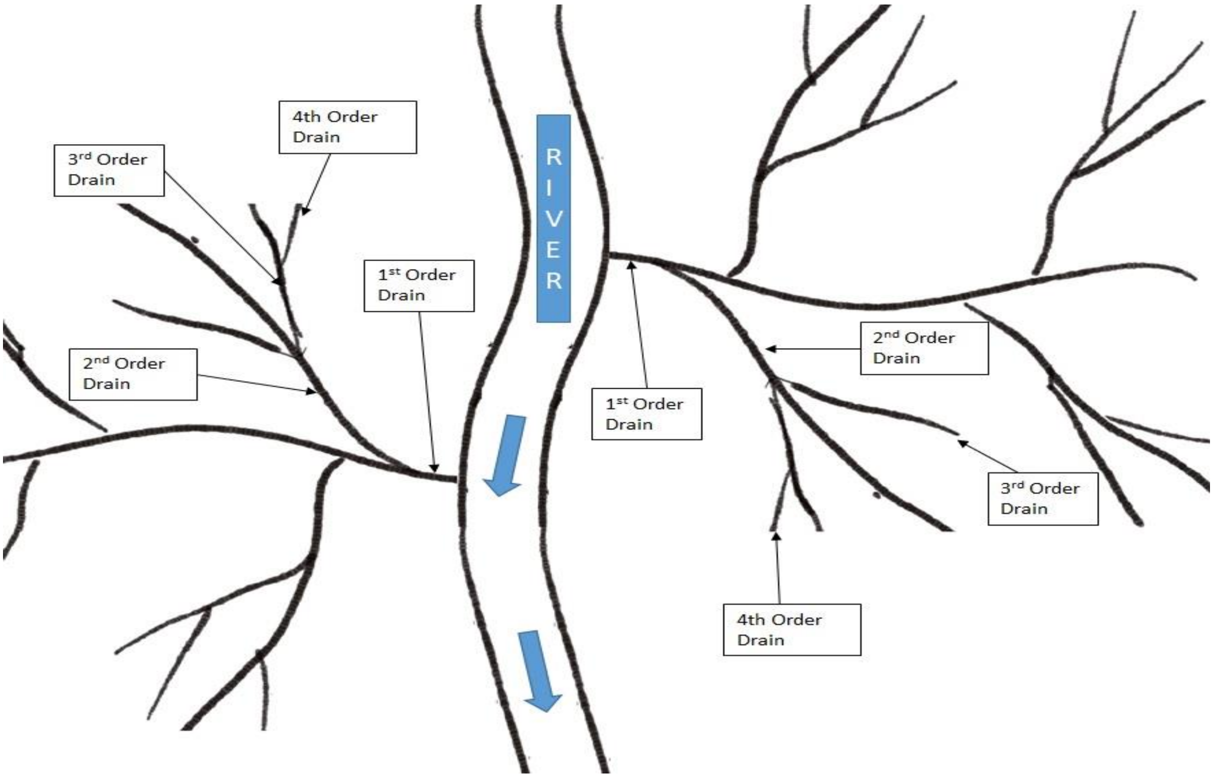

Figure 1 Drainage pattern of any city/town

Based on drain data available for River Ganga and its tributaries, categorization of drains has been made considering their hydrological characteristics namely, flow, pollution load and physical characteristics, which may influence selection of drain wastewater treatment technology.

Flow – Based on flow drain can be classified as,

- <20MLD – Minor Drain
- 20 – 50 MLD – Medium Drain
- >50 MLD – Major Drain

Pollution Load – Based on pollution load in terms of BOD concentration, drains can be classified as,

- <50 mg/l – Low Pollution Load
- 50-100 mg/l – Modern Pollution Load
- >100 mg/l – High Pollution Load

Width – Based on channel width, drains can be classified as,

- <3m – Narrow Drain
- 3 – 15m – Wide Drain
- >15m – Broad Drain

Drain could also be characterized based on the criteria such as drain traversing through hilly terrain, rocky terrain, plain, marshy area and draining into different recipient water body like river, lakes, pond and sea.

4. ALTERNATIVE TREATMENT TECHNOLOGIES

4.1 IN-SITU BIOREMEDIATION TECHNIQUES

In-Situ bioremediation techniques involve treatment at the site using aquatic plants and/or microbial remediation methods. *In-Situ* treatment systems can be commissioned in lower time duration (few months only), is easy to operate, and requires less energy as compared to conventional treatment technologies. *In-situ* treatment, depending on effluent characteristics, site conditions, and type of treatment systems, may either provide desired quality of treated effluent or act as supplementary to conventional treatment technologies. In any case, wherever feasible, it can be used as an interim remedial measure and help in reducing pollution load or polishing of treated effluent from Sewage Treatment Plants. The common *in-situ* treatment systems are Microbial Bioremediation, Phytoremediation, Constructed Wetland System and Root Zone Treatment. Adequate space and appropriate flow are general requirements for adoption of these technologies. Details of above mentioned *In-situ* bioremediation techniques indicating methodology, parameters for the feasibility assessment, existing experiences, etc. are as follow:

4.1.1 Phytoremediation

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. Phytoremediation involves the removal of organic compounds and nutrients from wastewater through bio-sorption/uptake by pollution-tolerant aquatic plants (such as algae, water hyacinth, duckweeds, etc.) growing in the wastewater. Quite often such plants grow along the littoral zones on either side of the drain.

4.1.2 Constructed Wetlands (CWs)

CWS also uses principle of Phytoremediation techniques. It integrates microbial bioremediation, phytoremediation and root-zone treatment in addition to providing the benefits of oxidation pond and physical filters.

Constructed wetlands (CWs) are scientifically proven and widely adopted across the world as alternative and complementary technology to conventional technologies for sewage treatment. A well-designed constructed wetland system will work on the same principle as that of STP but with greater microbial diversity associated with diverse plant species that effectively biodegrade organics and other pollutants in sewage and without energy.

A constructed wetland is highly versatile and can be designed for drains that have different topography hydraulics and physical characteristics of the drain (width, length, height). A constructed wetland system can be used as primary/ secondary/ tertiary treatment and with continuous flow. Figure 2 depicts schematic flow diagram of a Constructed Wetland System.

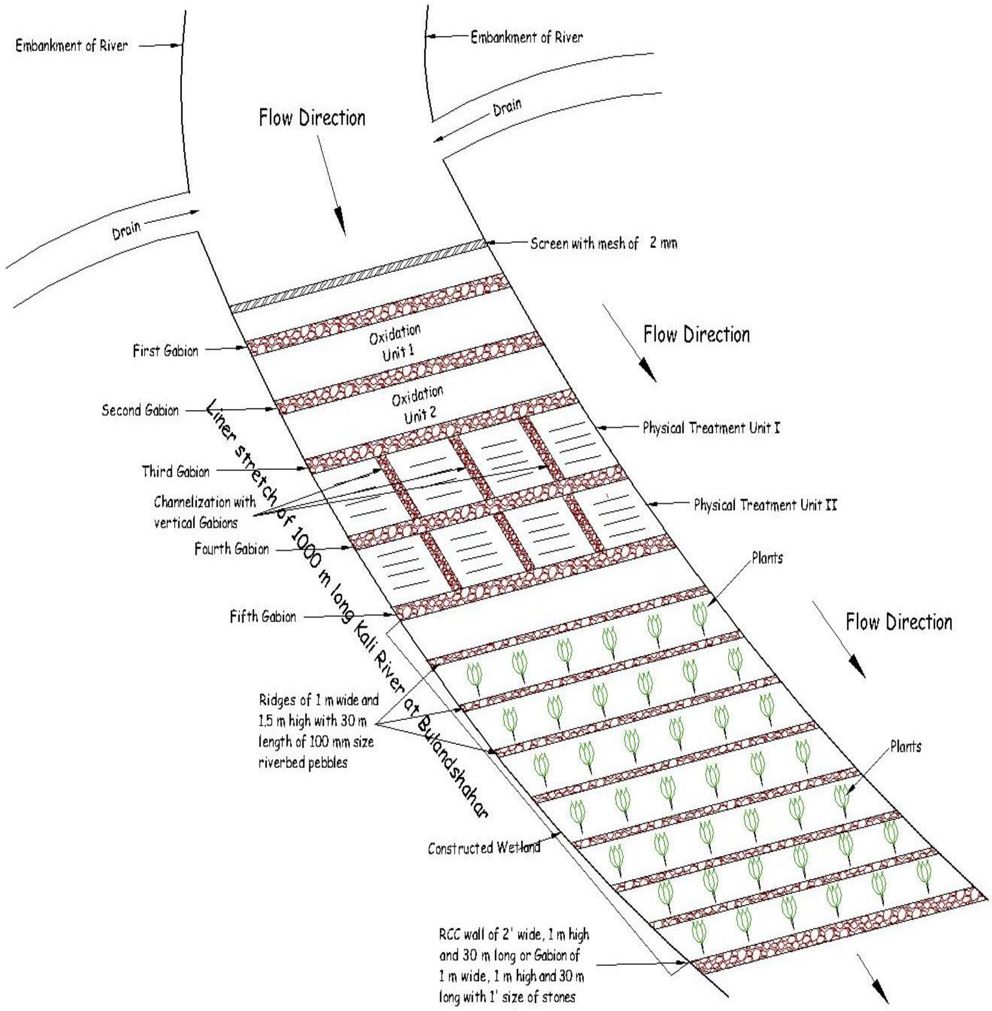

Figure 2 Schematic Diagram of Constructed Wetland Systems

A typical CW system should have the following components:

i. An aerobic oxidation pond with depth of water ranging from < 1m to 5m; water may be retained for at least 8-10 hours and consequently there may be slight rise in the water level (up to 30cm) from the normal water level in the drain.
   (a) there may be a screen (iron mash having 4-10 mm aperture) before the oxidation pond to remove solid waste and another screen (2-4 mm aperture) before water

enters into two physical filter tanks / chambers/ zones/ channels from oxidation pond.

ii. Three physical filter tanks/ chambers/ channels/ zones are ideal for efficient functioning; the physical filter chambers are separated by gabions of boulders of different sizes and embedded in iron mesh.
   (a) the first chamber/ channel/ zone is separated from the second chamber by a gabion made of boulders of 2' within the chamber channel and there will be 3 ridges made of stones/ pebbles of 200 to 250 mm.
   (b) The second chamber is separated from third chamber by a gabion made of boulders of 1’ size with 3-4 ridges of pebbles of 180 mm.
   (c) The third chamber is separated from the constructed wetland by gabion made of boulders of 1’ size with 3 to 4 ridges of river bed pebbles of 150 -120 mm.

iii. Constructed wetland having 5-10 furrows of 1 to 4 m width separated by ridges of 1 m high, 0.5m wide and composed of river bed pebbles of 80-50 mm size.

iv. Cascade outlet is made of boulders, stones and pebbles with gentle slope from the overflow of the constructed wetlands. Water coming out from the cascade can be recycled /stored in stagnant water bodies / wetland or channelized into the downstream of the drain or river.

Note:

i. The height of gabions should be 1.0 m 1.5 m high and usually above the water level in the channels/ chambers/ ponds/ zones.

ii. The typical CW system outlined above is for in situ biological remediation where the sides of the chambers/ ponds/ channels / zones are the embankments of the drains.

iii. For ex-situ biological remediation, the four sides of chambers/ponds/ tanks should be made of stone meshed walls of 1.5 -2 m high and 0.5 m – 1 m wide and all the components should be contiguous with gradient so that water flows on its own. If a gradient does not exist, a gradient channel has to be constructed.

4.1.3 Microbial Bioremediation

Microbial bioremediation involves periodic or continuous dosing of special waste-treating microbes, fungi and /or plants and their products (such as enzymes) in adequate quantity to the wastewater mass. The effectiveness of bioremediation depends on both the wastewater characteristics, the microorganisms and products that are used for dosing, the dosing amount, frequency of dosing and the environmental conditions.

Microbial bioremediation could be intrinsic (within the drain using natural consortia of microorganisms) or in vitro (using an engineered treatment system).

Microorganisms are used to treat mainly the organic matter; small quantity of inorganic materials and metals are also consumed as nutrients. Direct use of enzymes is done in biochemical treatment. It may be noted that aerobic microbes need less time, whereas anaerobic microbes need more time to degrade the waste.

Flow and retention time: This type of bioremediation requires retention time of 20 -30 hours, therefore may be suitable for drains with low flow.

Output of the process could vary where flow rates are variable and high, which could partly be due to rapid wash out of the material dosed from drains during high flow pulses. Drains often need interventions to slow down the flow rates. Also, the process being inherently slow will achieve good performance in larger span of time.

Domestic wastewater also gets mixed with the effluents from industries which invariably carry inorganic pollutants thereby impacting the microbial load. While there have been claims of successful treatment of municipal wastewater by bioremediation with various microorganisms and inoculums, these claims require reverification for a sustained period.

The system requires a kind of bio-reactor to meet the retention time and as such it requires a large area /stretch to provide the requisite retention time and the microbial diversity is limited and is composed of consortia of known microbes. There is recurring cost for maintaining microbial consortia as bio-media has to be added in running stream at regular intervals.

Further, the successful use of this bioremediation technique for in-situ treatment of wastewater-carrying drains, would necessitate periodic removal of bio-sludge generated over time from the drains to avoid choking of the drains and/or addition of pollution load on the receiving water body by transporting the sludge generated.

There is a requirement for well-defined specifications in case of this type of bioremediation since the microbial composition and doses are usually trade secrets and claims are unverifiable and comparable.

Current application of microbial bioremediation carried out by NMCG in 144 drains depicts better results in drains having flow less than 10 MLD. Therefore, such intervention can be applied in low hydraulic load and its expected outcome shall be within 50 %.

4.2 Ex-Situ Remediation Techniques

Ex-situ remediation technique includes constructed wetland, waste stabilization pond, aerated lagoon and oxidation pond. Design and performance details are attached as Annexure-I. Details of ex-situ techniques are given below:

4.2.1 Waste stabilization pond

Waste or Wastewater Stabilization Ponds (WSPs) are large, man-made water bodies in which Blackwater, greywater or faecal sludge are treated by natural occurring processes and the influence of solar light, wind, microorganisms and algae. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds,

(1) anaerobic,
(2) facultative and
(3) aerobic (maturation),

each with different treatment and design characteristics. WSPs are low-cost for O&M and BOD and pathogen removal is high. However, large surface areas and expert design are required. Effluent contains nutrients (e.g. N and P) and is therefore appropriate for reuse in agriculture, but not for direct discharge in surface waters.

4.2.2 Mechanically Aerated Lagoon

Mechanically aerated lagoons are earthen basins generally 2.5 to 5m deep, provided with mechanical aerators installed on floats or fixed columns. Raw sewage is fed from one end into lagoon (after screening) and it leaves from the other end after desired period of aeration. Aerated lagoons are smaller in size (less than 10-20%) compared to waste stabilization ponds. Three types of aerated lagoons can be distinguished as mentioned below:

1. Facultative aerated Lagoons

Facultative aerated lagoons consist of a shallow basin in which settleable solids introduced by the wastewater settle to the bottom to form a sludge layer that decomposes anaerobically. Biodegradable organic materials that do not settle are degraded aerobically. The term facultative aerated describes the aerobic-anaerobic nature of the lagoon - an anaerobic bottom region covered by an aerobic top layer. Process of oxygenation is enhanced through floating aerators in upper section of lagoon. Lower section of lagoon maintains anaerobic conditions. The power input per unit volume is only sufficient for diffusing required amount of oxygen into liquid, but not sufficient for maintaining all the solids in suspension (Figure – 3).

Consequently, some of the suspended solids entering the Lagoon and some of the new solids produced in the lagoon as a result of substrate removal tend to settle down and undergo anaerobic decomposition at the bottom. They are capable of giving 70-90% BOD removal from domestic sewage.

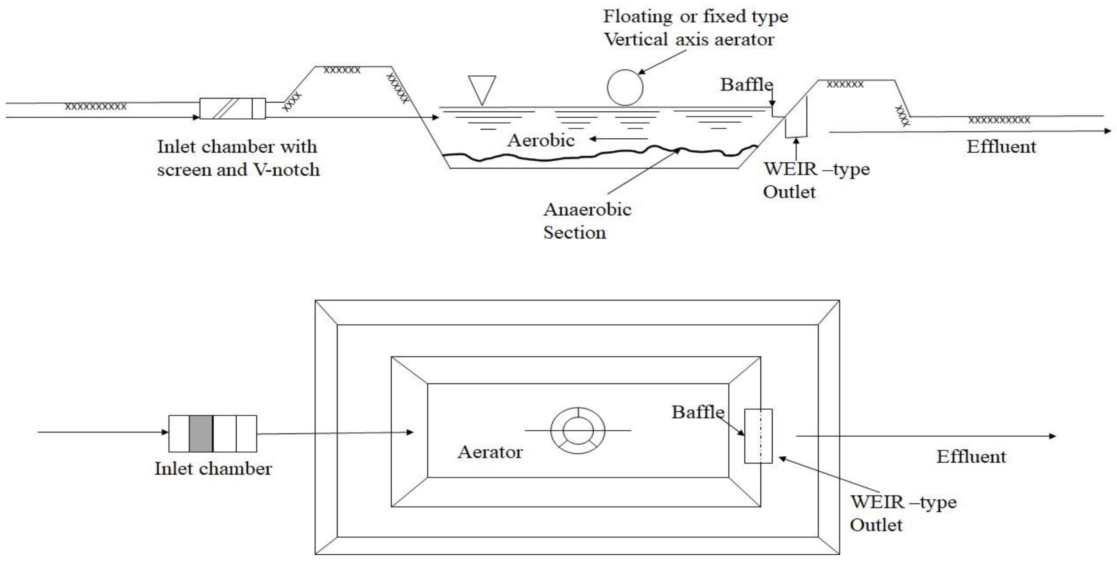

Figure 3: Mechanical aerated facultative lagoon

2. **Aerobic flow-through Lagoons**

Aerobic flow-through lagoons use aerators to mix the effluent in the pond and add oxygen to the wastewater. In aerobic flow through lagoons, oxygen transfer is maintained throughout the depth of the lagoon. The power level is high enough not only to diffuse adequate oxygen into the liquid but also to keep all solids in suspension as in an activated sludge aeration tank (Figure – 4). Additional treatment (such as stabilization pond) is necessary if better BOD and solid removal is desired.

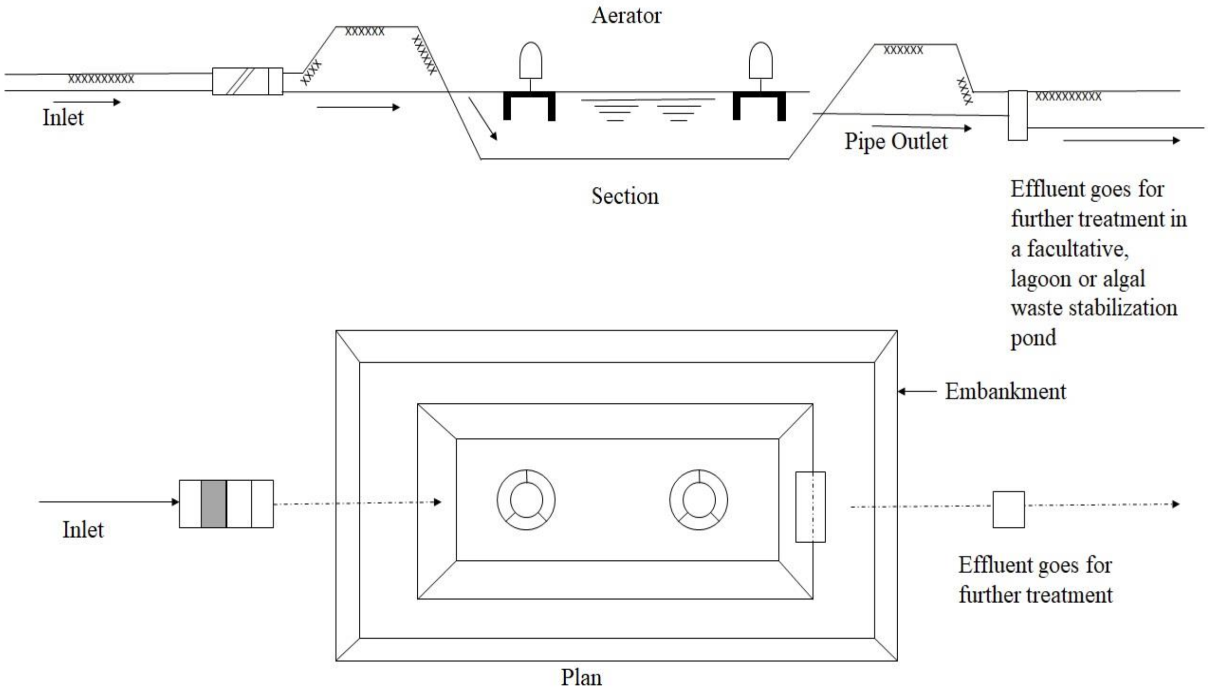

Figure 4 Mechanical aerated flow through type lagoon

3. **Aerobic lagoons with recycling of solids**

In aerobic lagoons, oxygenation of effluent and retention of recyclable solids is carried out. In these lagoons, power input level is sufficient to meet the oxygen requirement as well as to keep all solids in suspension. The efficiency of BOD removal in these types of lagoons can be as high as 95-98%. and nitrification can also be achieved (Figure – 5).

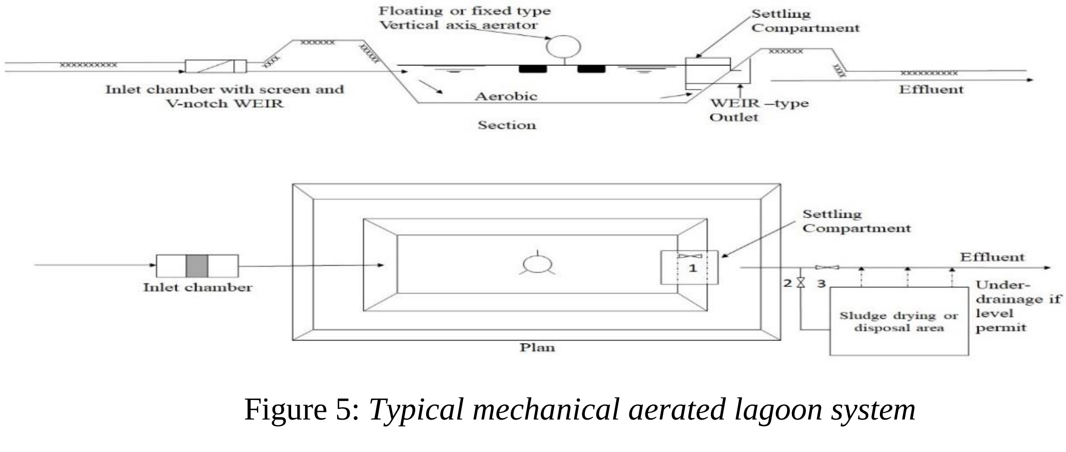

Figure 5: *Typical mechanical aerated lagoon system*

5. CRITERIA FOR SELECTION OF ALTERNATIVE TREATMENT TECHNOLOGIES FOR REJUVENATION OF DRAINS

The effective biological *in-situ* treatment system should need the following requirements:

i) *In situ* treatment should be different from conventional centralized or de-centralized treatment system.

ii) It should be a rapid system having commissioning time of less than six to twelve months.

iii) The *in situ* treatment system should have the ability to treat the sewage in a continuous manner throughout the year.

iv) The treatment system must have a well-defined inlet and outlet along with minimum modification in natural drain structure.

v) The treatment system should work on zero/negligible power consumption.

vi) The treatment system should have a designed life and minimum operational constraints.

vii) It should not have high capital cost and recurring cost as compared with conventional *ex situ* treatment technology currently in practice.

viii) The design life should be up to 15 years at optimum operation condition.

ix) In case of drains having flow >20 MLD, the system may be developed in modular form having 2-3 blocks of treatment within one treatment stretch.

x) The treatment system must be capable of degrading/reducing the soluble and insoluble organic materials.

xi) Removal efficiency of soluble BOD at the final designated outlet should not be less than 60% in terms of organic load reduction with treated wastewater quality at designated outlet of pH 6.5-8.5, DO ≥5mg/land BOD ≤ 20 mg/l, whichever is stringent.

xii) *In-situ* treatment shall be accompanied with pre-treatment/ physical solid liquid separation as drains carry large quantity of solid waste.

xiii) The generated sludge must be quantified and cleaned based on requirement preferentially at every 15 days within the defined stretch. If required, dredging should be done to maintain the depth.

xiv) The system must not hinder the flow and not result in ponding at the upstream site of the drain.

xv) Flow measuring device (such as V-notch, EM meter etc.) may be installed at the inlet/outlet of the treatment stretch so as to control the treatment based on flow and assessment of daily treated volume.

xvi) Treatment system shall be installed at such a location/manner and for such volume of drains that the treated effluent quality at defined outlet shall be maintained throughout the entire downstream stretch of the drain till confluence with the river. If required, treatment system could be set up in series in entire drain stretch.

xvii) Treatment system shall be set up for inlet wastewater quality of BOD≥40mg/l.

6. SCHEMES/MODELS FOR DIFFERENT ORDERS OF DRAIN

Categorization of drains are made based on the experience of drain monitoring in Ganga Catchment. Schemes/ Models defined for treatment are generic and suggestive in nature and any application of such model requires specific design as per site requirements. The land requirements mentioned are indicative and it shall be worked out as per the design criteria. Summary of different treatment schemes is shown in table 1

6.1 Model 1: Minor sewage drain with moderate pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation ponds/ Facultative pond (1-2 no.) + Physical Treatment unit + wetland/phytoremediation or waste stabilization pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 6). In *in-situ* treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

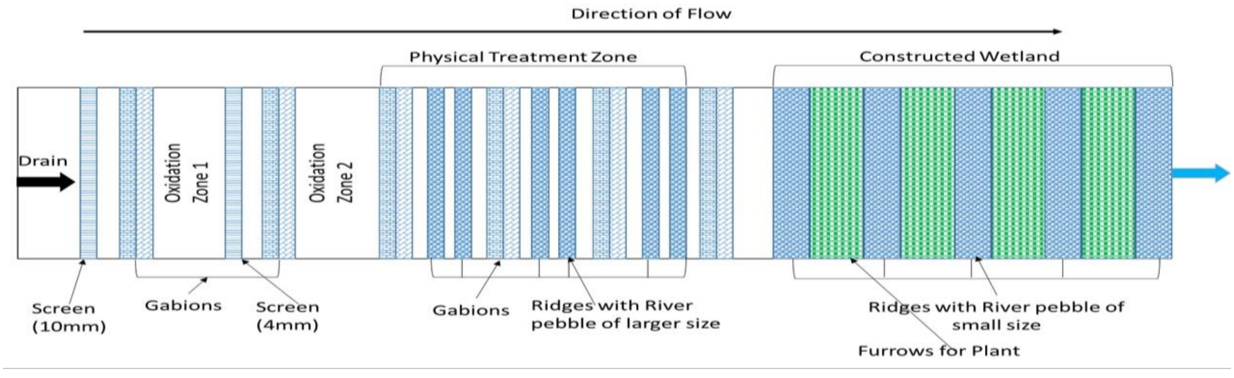

Figure 6 Schematic layout of *in-situ* Biological Remediation

6.2 Model 2: Minor sewage drain with moderate pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	3-15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation ponds/ Facultative pond (1-2 no.) + Physical Treatment unit + wetland/phytoremediation or waste stabilization pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 2nd and 3rd order drains. For hilly areas, such system has to be developed in the marshy depressions/valleys. In other words, it will be developed at the confluence of the drain with depression /low lying area in the valley.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised In-situ/ Ex-situ based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 7).

e) **Schematic diagram:**

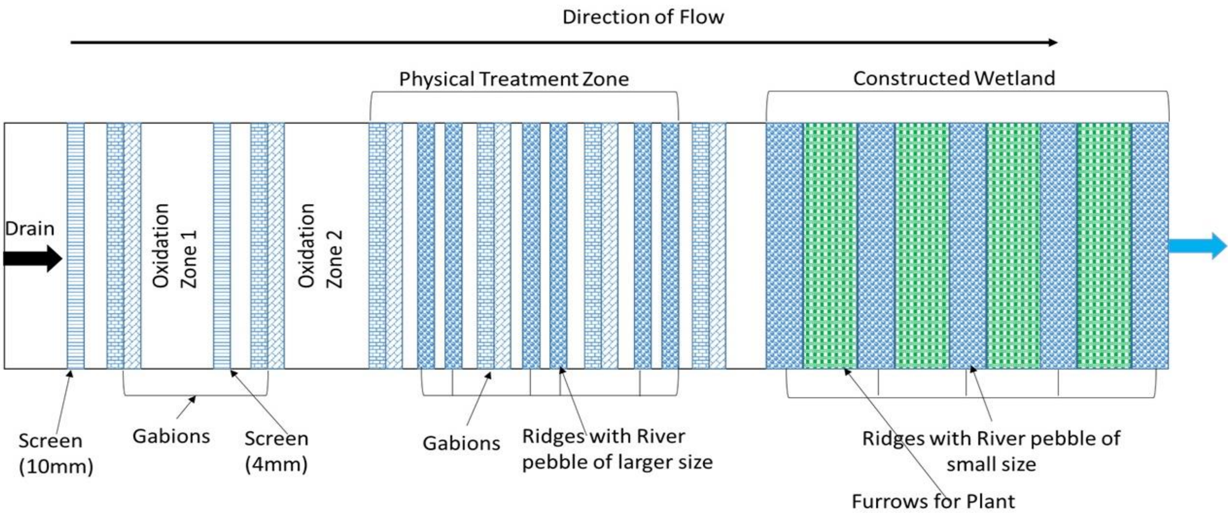

Figure 7 Schematic layout of *in-situ* Biological Remediation

6.3 Model 3: Minor sewage drain with moderate pollution load & narrow channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	< 3 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation ponds/ Facultative pond (1-2 no.) + Physical Treatment unit + wetland/phytoremediation or waste stabilization pond or Ex-Situ Activated Sludge Method

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with channel width of less than 3m. This type of model is suitable for 3rd or higher order drains. For hilly areas, such system has to developed in the marshy depressions/valleys. In other words, it will be developed at the confluence of the drain with depression /low lying area in the valley.

d) **Design aspect:** Due to less flow width, In- situ treatment is generally not feasible in these categories of drains. Ex situ model may be best suitable for providing sufficient hydraulic retention time in oxidation pond + wetland system or Waste Stabilization Pond as per the space available. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 8).

e) **Schematic diagram:**

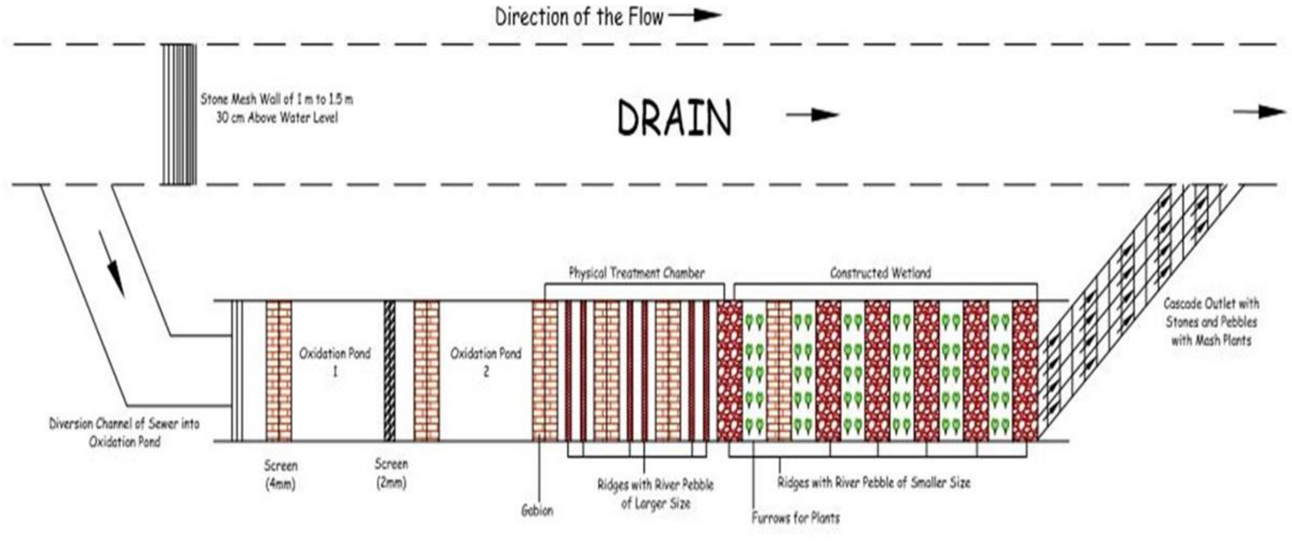

Figure 8 Schematic layout of *ex-situ* Biological Remediation

6.4 Model 4: Minor sewage drain with high pollution load &broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	0.5 - 2 Meter

- Organic Loading

BOD	:	>100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation pond + Physical Treatment unit + constructed wetland system or Waste Stabilization Pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with channel width more than 15 m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 9). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

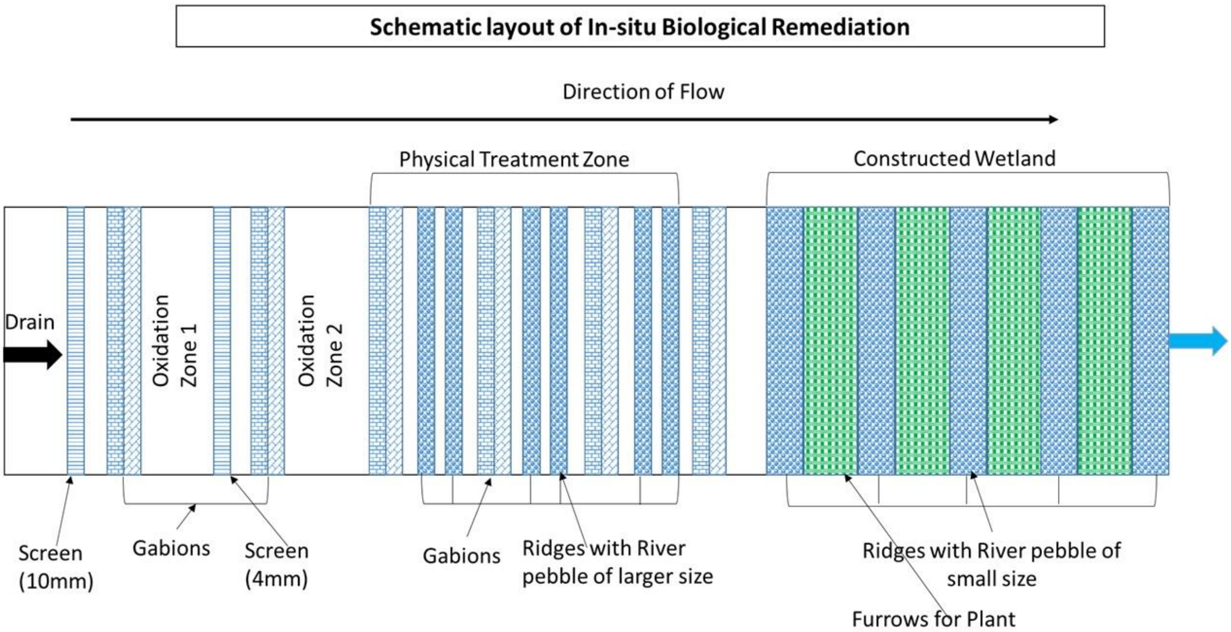

Figure 9: Schematic layout of *in-situ* Biological Remediation.

6.5 Model 5: Minor sewage drain with high pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	3- 15 Meter
Depth of Flowing Water	:	0.5 - 2 Meter

- Organic Loading

BOD	:	>100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation pond + Physical Treatment unit + constructed wetland system or Waste Stabilization Pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with channel width 3-15 m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised In-situ/ Ex-situ based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure 10).

e) **Schematic diagram:**

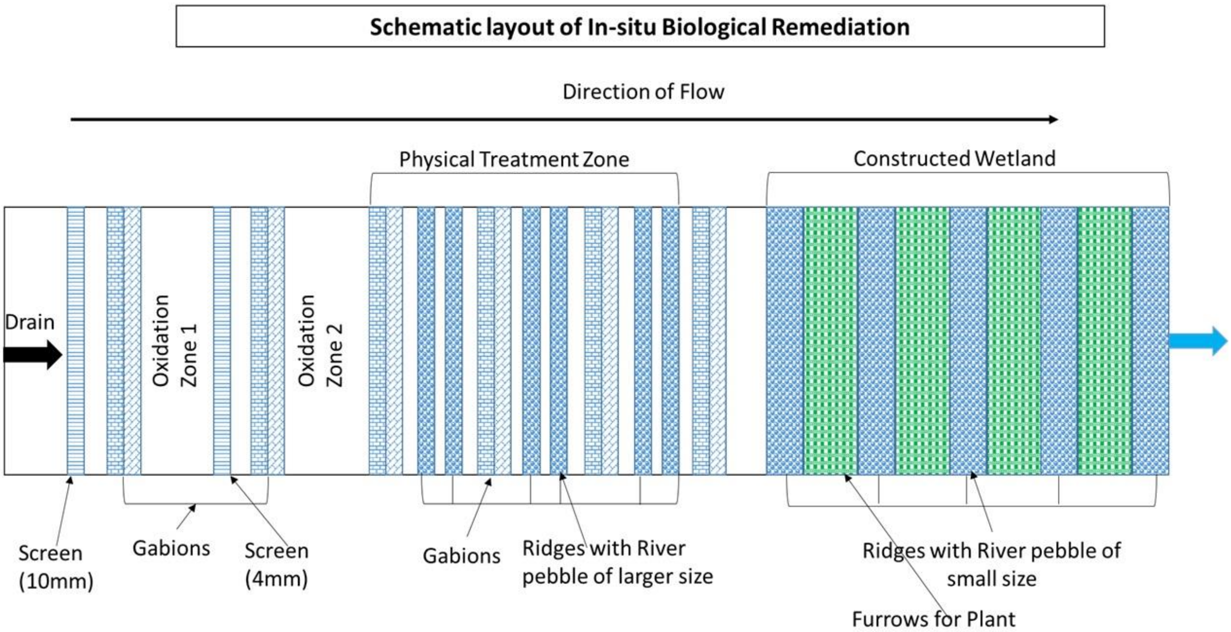

Figure 50 Schematic layout of *in-situ* Biological Remediation.

6.6 Model 6: Minor sewage drain with high pollution load& narrow channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System
  Width of Drain : < 3 Meter
  Depth of Flowing Water : 0.5 - 2 Meter
- Organic Loading
  BOD : >100 mg/l
- Hydraulic Loading
  Flow : < 20 MLD

b) **Treatment scheme:** Oxidation pond + wetland system or Waste Stabilization Pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying only low pollution load untreated sewage with channel width of less than 3m. This type of model is suitable for 3rd or higher order drains.

d) **Design aspect:** Due to less flow width, In- situ treatment is generally not feasible in these categories of drains. Ex situ model may be best suitable for providing sufficient hydraulic retention time in oxidation pond +wetland system or Waste Stabilization Pond as per the space available. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 11).

e) **Schematic diagram:**

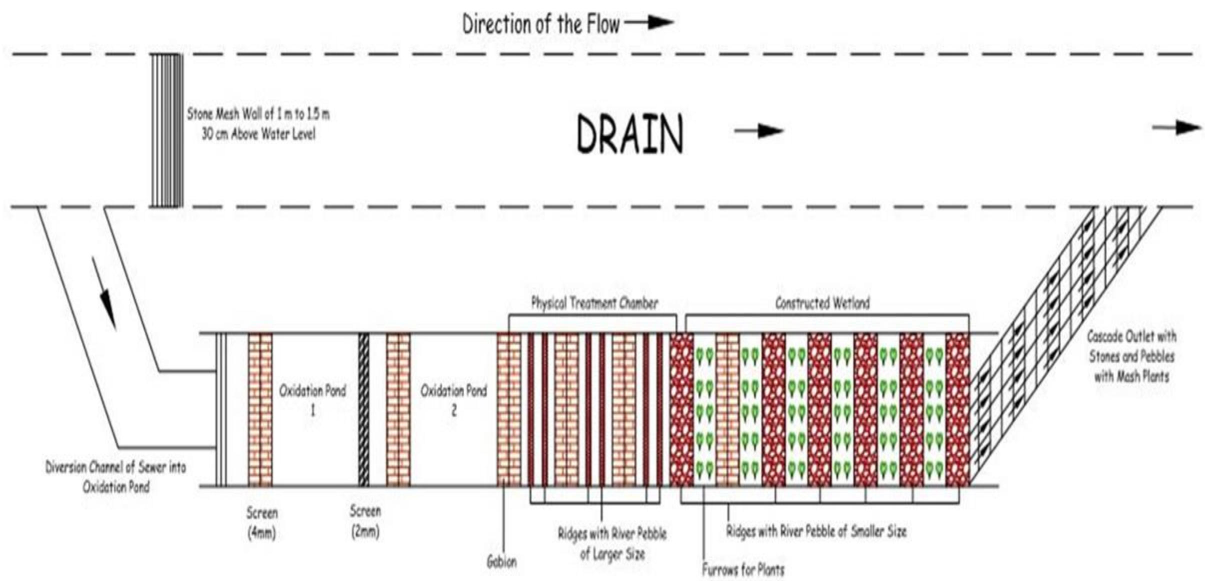

Figure 11: Schematic layout of *ex-situ* Biological Remediation.

6.7 Model 7: Medium sewage drain with low pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 50 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying only low pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 12). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

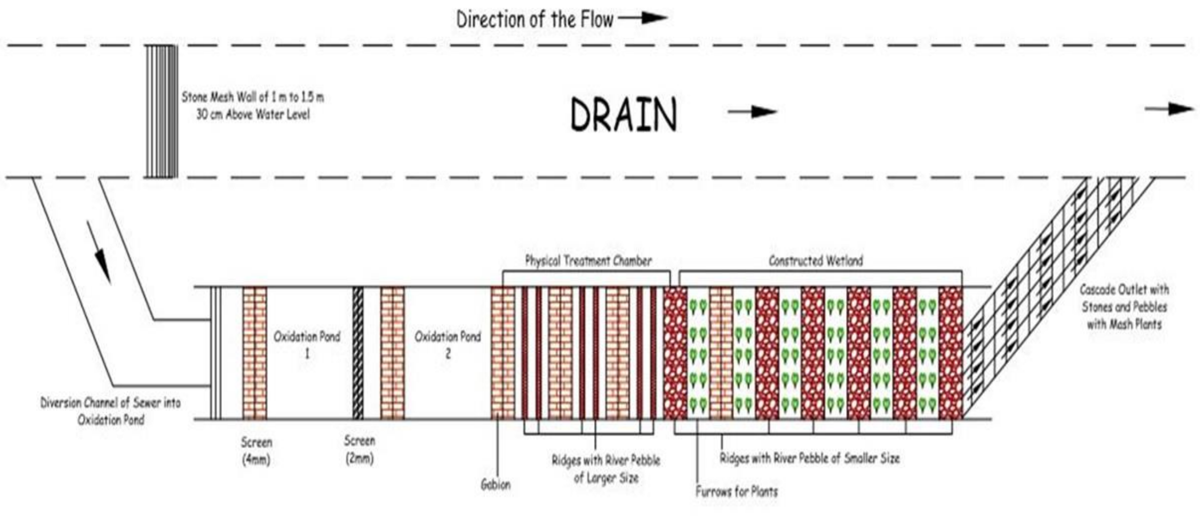

Figure 62 Schematic layout of *ex-situ* Biological Remediation

6.8 Model 8: Medium sewage drain with low pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	3- 15 Meter
Depth of Flowing Water	:	1 - 2 Meter

- Organic Loading

BOD	:	< 50 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying only low pollution load untreated sewage with channel width of 3-15m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised as In-situ/ Ex-situ based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 13).

e) **Schematic diagram:**

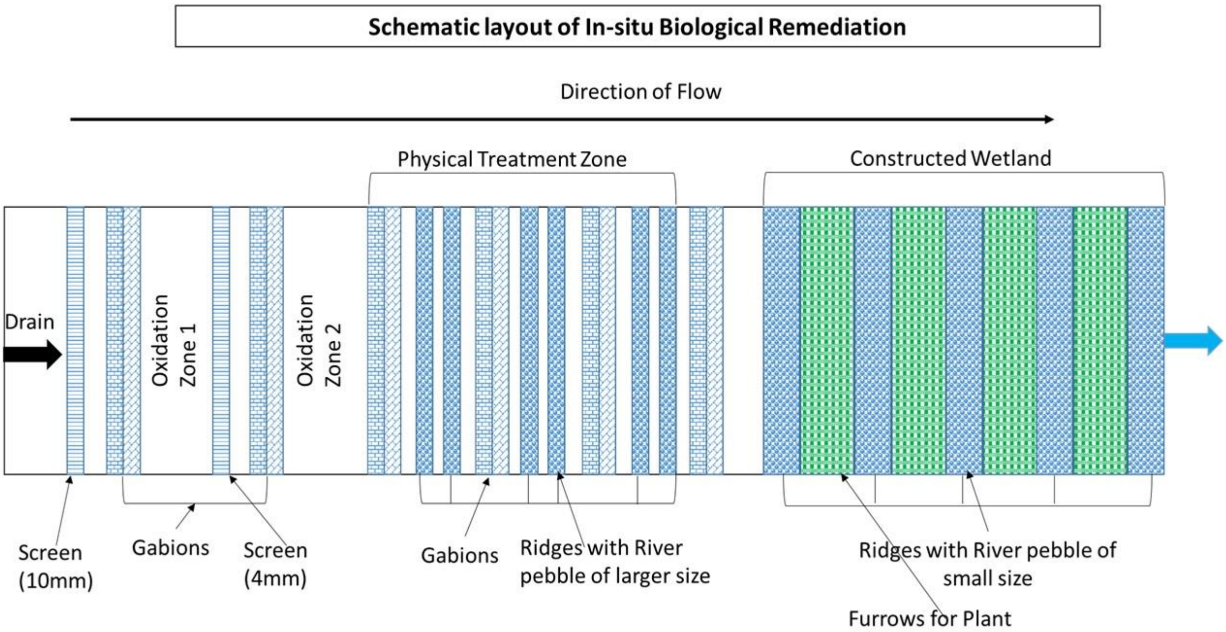

Figure 13 Schematic layout of *in-situ* Biological Remediation.

6.9 Model 9: Medium sewage drain with moderate pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 14). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

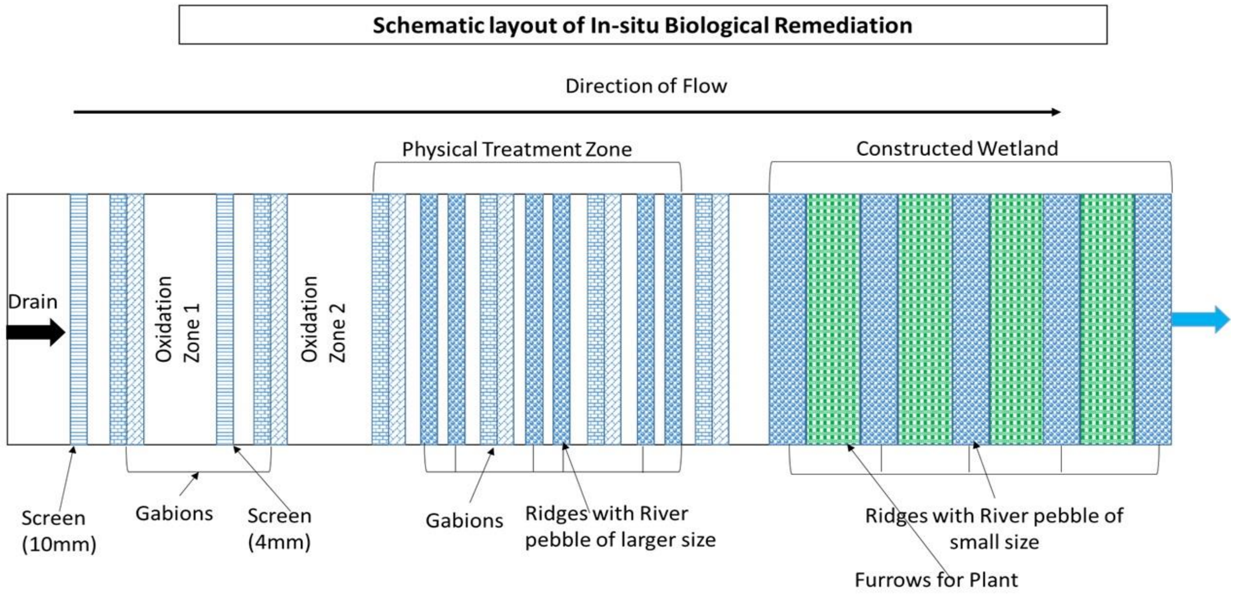

Figure 14: Schematic layout of *in-situ* Biological Remediation.

6.10 Model 10: Medium sewage drain with moderate pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	3- 15 Meter
Depth of Flowing Water	:	1 - 2 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond (2 no.) + Physical Treatment unit -2 no.) + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load untreated sewage with channel width of 3-15m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised as *In-situ/ Ex-situ* based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 15).

e) **Schematic diagram:**

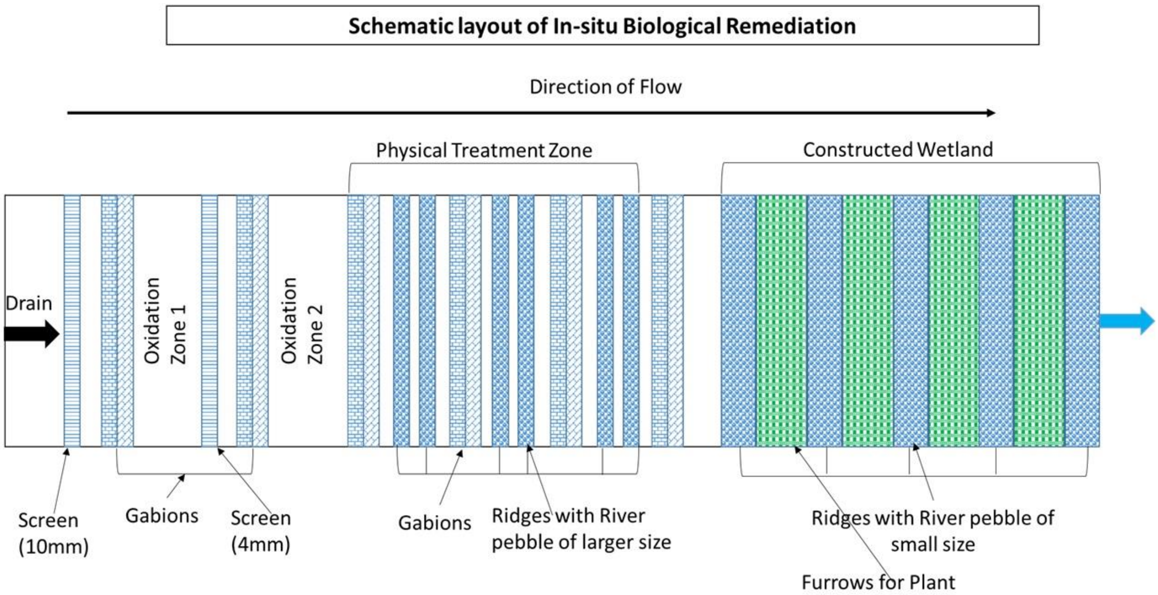

Figure 15: Schematic layout of *in-situ* Biological Remediation.

6.11 Model 11: Medium sewage drain with high pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	> 100 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 16). In *in-situ* treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

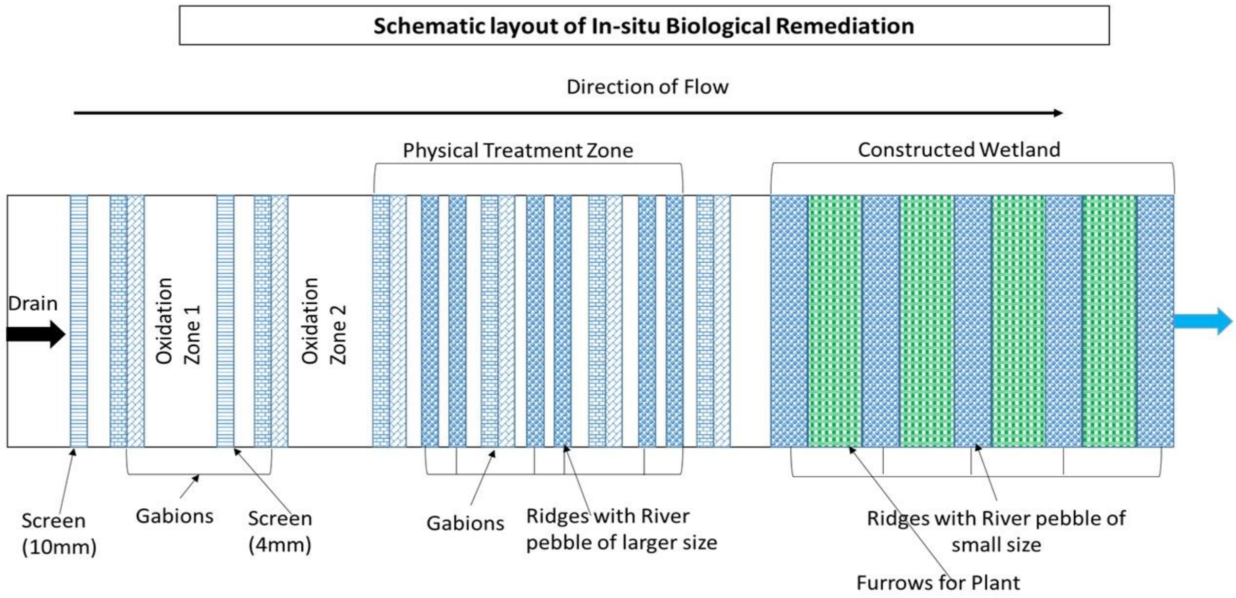

Figure 76: Schematic layout of *in-situ* Biological Remediation.

6.12 Model 12: Medium sewage drain with very high pollution load & broader channel

a) **Drain hydrological characteristics:**

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	> 200 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Pond with mud ball technology + Facultative ponds (1-2 no.) + Lagoon + oxidation pond + Lagoon+ wetland or Oxidation pond + Physical Treatment unit + Constructed wetland

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 17). In *in-situ* treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

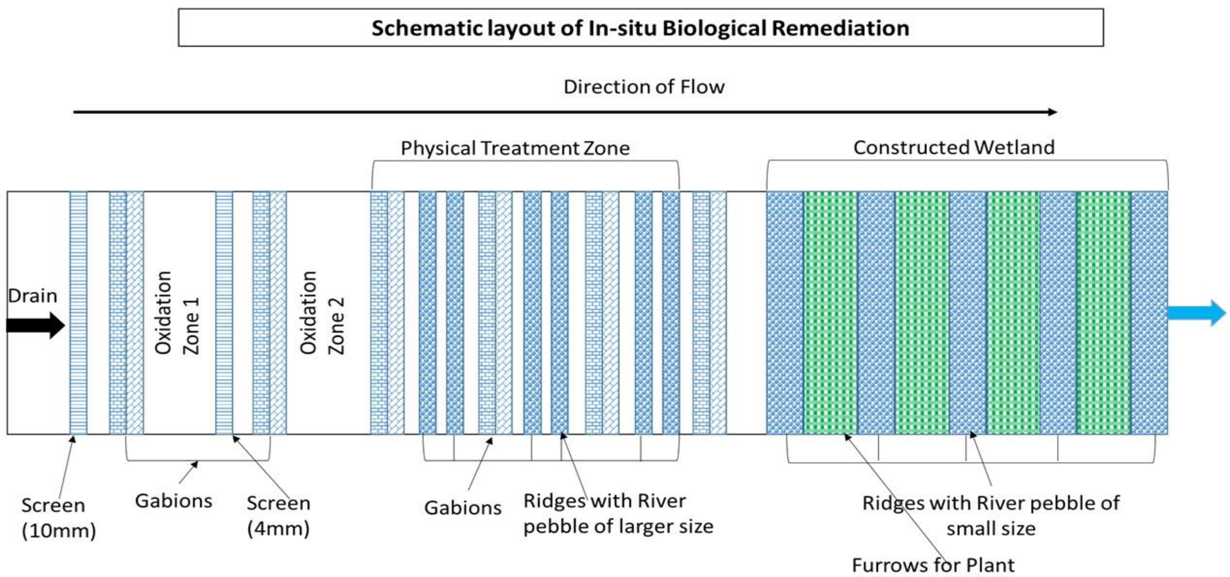

Figure 8 Schematic layout of *in-situ* Biological Remediation.

6.13 Model 13: Major sewage drain with low high pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 50 mg/l

- Hydraulic Loading

Flow	:	50 -100 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + Lagoon+ wetland or Oxidation pond + Physical Treatment unit + Constructed wetland

c) **Applicability:** This type of treatment scheme is suitable for drains carrying low pollution load (untreated sewage only) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 18). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

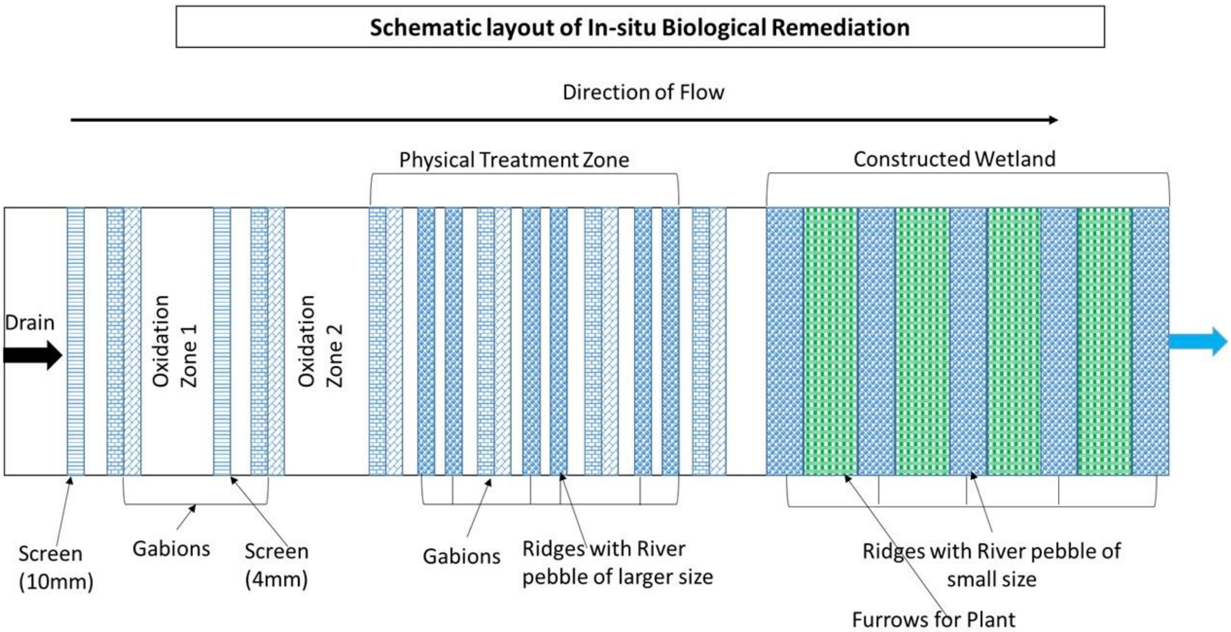

Figure 18: Schematic layout of *in-situ* Biological Remediation.

6.14 Model 14: Major sewage drain with moderate pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	50 -100 MLD

b) **Treatment scheme:** Facultative ponds (2 no.) + Lagoon + oxidation pond + Lagoon+ wetland or Oxidation pond (2 no.) + Physical Treatment unit (2 no.) + Constructed wetland

c) **Applicability:** This type of treatment scheme is suitable for drains carrying low pollution load (untreated sewage only) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 19). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

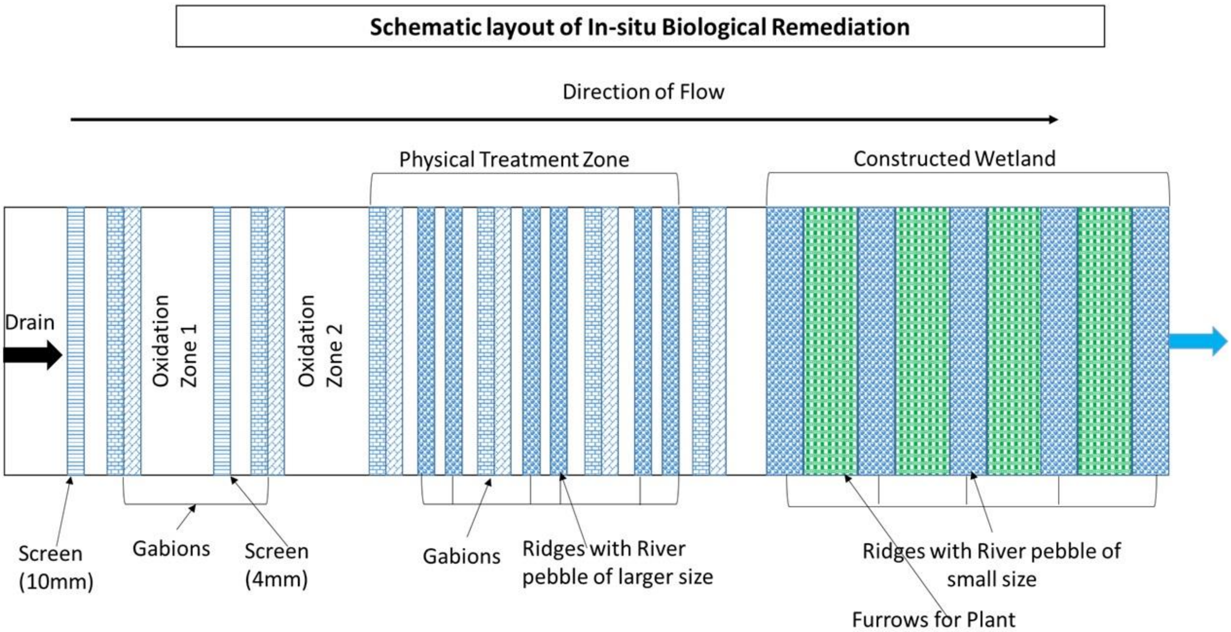

Figure 19: Schematic layout of *in-situ* Biological Remediation.

6.15 Model 15: Major sewage drain with low pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 50 mg/l

- Hydraulic Loading

Flow	:	>100 MLD

b) **Treatment scheme:** Facultative ponds (2 no.) + Lagoon + oxidation pond (2 no.) + Lagoon+ wetland or Oxidation pond (2 no.) + Physical Treatment unit (2 no.) + Constructed wetland

c) **Applicability:** This type of treatment scheme can be used for biological remediation of polluted rivulets /rivers/major storm drains of cities by channelizing the drain bed up to 15 channels (distribution channels) and the CW stretch may extend up to 1000 m (1 km) and there may be more than 15 such stretches across a distance of 500 km (linear). The width of gabions should be at least more than 4m, as the river carry storm water.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 20). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

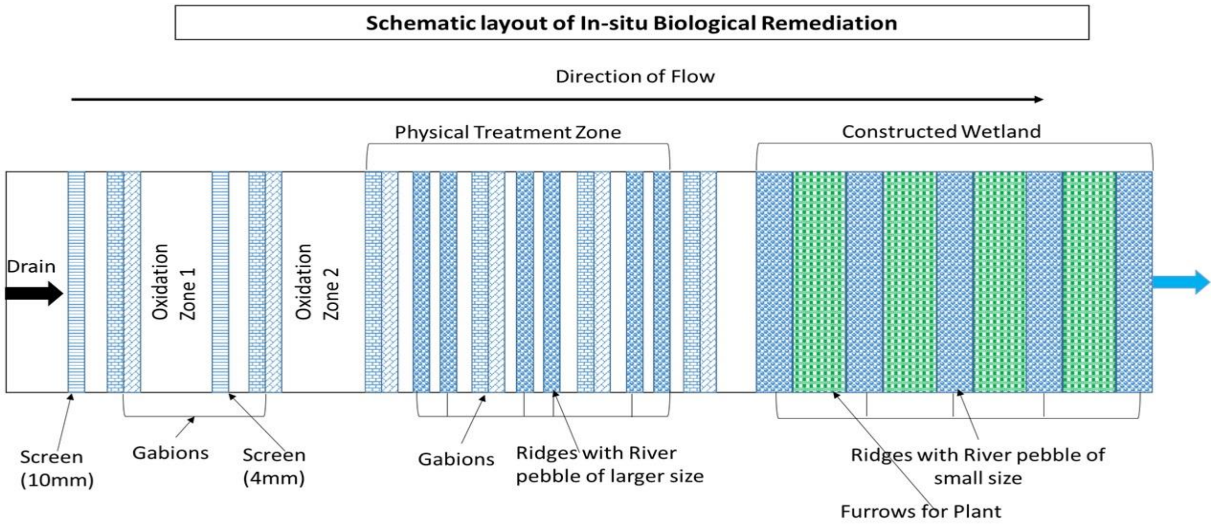

Figure 20: Schematic layout of *in-situ* Biological Remediation.

Table 1: Decision matrix for design of In-Situ / Ex-situ remediation techniques

Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
1.	Minor sewage drain with moderate pollution load & broader channel	< 20	< 100	> 15	Oxidation pond/ Facultative pond+ Lagoon+ Wetland or Waste Stabilization Pond or In-situ Activated Sludge Method	In situ	Lagoon sludge removal frequency – every 3 month, ponds HRT 20 hr min.
2.	Minor sewage drain with moderate pollution load & wide channel	< 20	< 100	3-15	Oxidation pond/ Facultative pond + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	Treatment unit may be in situ/ex situ as per available space
3.	Minor sewage drain with moderate pollution load & narrow channel	< 20	< 100	< 3	Oxidation pond/ Facultative pond + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	Oxidation pond will be ex situ & wet land may be in situ/ ex situ
4.	Minor sewage drain with high pollution load & broader channel	< 20	> 100	> 15	Facultative pond/Trickling filter + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ	Sludge may be recycled partly in Facultative Trickling filler. Toxic sludge need to be disposed as per guideline

Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
5.	Minor sewage drain with high pollution load & wide channel	< 20	> 100	3-15	Facultative pond/Trickling filter + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	All Treatment units may be in situ/ex situ as per available space
6.	Minor sewage drain with high pollution load & narrow channel	< 20	> 100	< 3	Facultative pond/Trickling filter + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	Pond/filter/Lagoon will be ex situ & wet land may be in situ/ ex situ
7.	Medium sewage drain with low pollution load & broader channel	< 50	< 50	> 15	Facultative pond + Lagoon + Oxidation pond +Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months
8.	Medium sewage drain with low pollution load & wide channel	< 50	< 50	3-15	Facultative pond + Lagoon + Oxidation pond +Wetland or Constructed Wet Land (CWS)	In situ/ Ex situ	All Treatment unit may be in situ/ex situ as per available space
9.	Medium sewage drain with moderate pollution load & broader channel	< 50	< 100	> 15	Facultative pond + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum

Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
10.	Medium sewage drain with moderate pollution load & wide channel	< 50	< 100	3-15	Facultative pond + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ/ Ex situ	All Treatment units may be in situ/ex situ as per available space
11.	Medium sewage drain with high pollution load & broader channel	< 50	> 100	> 15	Facultative pond (2 no.) + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum
12.	Medium sewage drain with very high pollution load & broader channel	< 50	> 200	> 15	Pond with mud ball technology Facultative pond (2 no.) + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum
13.	Major sewage drain with low high pollution load & broader channel	50-100	< 50	> 15	Facultative pond + Oxidation pond (1-2 no.)+ Lagoon + +Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months
14.	Major sewage drain with moderate pollution load & broader channel	50-100	< 100	> 15	Facultative pond + Oxidation pond (1-2 no.)+ Lagoon + +Wetland or	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum

Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
					Constructed Wet Land (CWS)		
15.	Major sewage drain with low pollution load & broader channel	> 100	< 50	> 15	Facultative pond (2 no.) + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum
Note: All above models are generic in nature and actual design may vary as per actual site specific requirement							

7. CHALLENGES WITH APPLICATION OF ALTERNATIVE BIOLOGICAL TREATMENT TECHNOLOGY

- Application of any *in-situ* bioremediation of wastewater requires obstruction wall (check dam / weir) to slow down the velocity of flowing water. Any flowing wastewater in storm water drains carry huge volume of floating material (solid waste, plastic waste etc.) and silt. Such obstruction to slow down of the velocity of wastewater results in trapping of floating material and deposition of silt.
- Siltation of drains will result in ponding of wastewater in upstream of such structures that may also result in flooding of upstream areas. Therefore, provisions must be made for regular removal and proper disposal of deposited silt. Floating matter collected also need to be disposed off in scientific manner.
- Spacing between the gabions need to be cleaned on regular basis as it may get choked with silt and floating materials.
- Efficiency decrease in monsoon due to high flow.
- It needs regular harvest of biomass and cleaning of physical filters.
- Difficult to operate when depth of water in drain is more than three feet.
- Slow process as compared to conventional treatment.
- Not effective in backwater, flood water from river on high tides.

8. CASE STUDIES ON DIFFERENT ALTERNATIVE TREATMENT TECHNOLOGIES

Case studies of some of the wastewater interception, diversion and treatment facilities based on alternative treatment technologies namely constructed wetland, soil biotechnology, oxidation pond, trickling filter and aerated lagoon are as under:

8.1 Constructed Wetland

a) Constructed wetland has been established at Neela Hauz lake near Sanjay Van by Centre for Environmental Management of Degraded Ecosystems (CEMDE), Delhi University in collaboration with DDA. The lake is fed by discharge from drain having 01 MLD flow. The constructed wetland effectively results in 90% reduction in BOD and has resulted in restoration of the Neela Hauz lake which was practically dead due to high pollution load. The project was started in November, 2016 and is currently in operation; it was constructed at a cost of Rs. 10 lakhs and requires annual harvest of dead biomass and annual cleaning of physical filters and removal of sludge from oxidation ponds.

b) In-situ constructed wetland system at Rajokari water body was installed by Irrigation and Flood Control Department, Delhi with a project cost of Rs. 77.19 lakhs. The water body is fed by a drain having flow of 600 KLD. There is 84% reduction in BOD in the water body post construction of the wetland. The wetland is currently in operation.

c) Ex-situ remediation for water body rejuvenation through Phytorid technology developed by CSIR-NEERI. This project has been implemented Pan India in 300 sites and is currently in operation in all the sites. The cost of the project was Rs 2.2 crore per

MLD for civil construction and O&M of Rs 20 Lakhs per MLD (including manpower, consumables, electricity, testing, contingency and miscellaneous items). The land requirement for the project is 1500 m2 per MLD. The technology is highly efficient with BOD and TSS of treated water reduced to ≤ 10 mg/l and ≤ 30 mg/l respectively.

d) In-situ restoration of drains viable for flow between 1-10 MLD through RENEU Technology developed by CSIR-NEERI. The restoration of six drains in Jhusi, Prayagraj was undertaken through this technology while work order has been received to implement RENEU in 10 drains at Gorakhpur. For implementation of this technology, drains having 1-10 MLD require a stretch of 180-200m while for drains having flow greater than 10 MLD, the stretch required will be 200-600m. The cost of the project was Rs Rs835 Lakhs per MLD for civil construction and O&M of Rs Rs255 Lakhs per MLD (including manpower, consumables, electricity, testing, contingency and miscellaneous items). The technology demonstrates 40% reduction in pollution with BOD and TSS of treated water reduced to ≤ 30 mg/l and ≤ 30 mg/l respectively.

e) Constructed wetlands are under commissioning at Bithoor to treat 2.4 MLD sewage generated from seven drains directly discharging in River Ganga from Bithoor town. The constructed wetlands are designed for in-situ treatment of sewage. During the last visit by CPCB officials, the wetlands were found to be under construction.

8.2 Soil Biotechnology

a) In Bah Bazar STP at Devprayag, soil biotechnology is adopted for treatment of 1.4 MLD sewage. An inspection of the STP by CPCB officials revealed that through soil biotechnology, a BOD and COD reduction of 80% and 76.39% respectively was achieved while TSS levels reduced by 78.53% and ammonical nitrogen showed a reduction of 66.66%. Thus, soil biotechnology is an effective treatment technology with only one drawback being that TDS reduced by only 6.48%.

8.3 Waste Stabilization Pond

a) In Anupshahar, an STP of 1.75 MLD at STP Zone B has adopted waste stabilization pond technology with five ponds in series for sewage treatment. The analysis report of treated samples from the STP indicated 96.77% reduction in BOD, 92.27% reduction in COD and 100% reduction in TSS. Phosphate and sulphate content also reduced by 52.67% and 35.71% respectively. However, it was observed that nitrate content reduced only by 3.84% and there was no reduction in TDS, faecal coliform. Thus, treated samples were found to comply with general discharge standards.

b) At STP of 0.85 MLD situated in Zone A of Anupshahar, U.P., the treatment technology is waste stabilization through five ponds in series for sewage treatment. The analysis report of treated samples from the STP indicated 74.48% reduction in BOD, 59% in COD and 81.39% in TSS. Also, there was marginal reduction in TDS (3.08%), sulphate (20.51%), chloride (10.2%) and phosphate (5.91%). However, there was increase in ammonical nitrogen by 22.72% and faecal coliform levels remained unchanged. The treated effluent complied with general discharge standards thus indicating that the in-situ treatment technology is effective despite increase in ammonical nitrogen.

c) At the Vindhyachal STP of 4 MLD capacity located in Mirzapur, U.P., waste stabilization pond technology has been adopted with a total of four ponds (with three different functions); first pond is anaerobic (28.4 mx49.6x5.5m), second is facultative (75.4 m x 148.5 m x 2.0 m), and two are maturation ponds (Maturation-1: 55.45 m x 150.4 m x 1.45 m; Maturation – 2: 56.5m x 150.4 m x 1.55 m). Analysis of samples from final outlet indicated a reduction of 77.5% in BOD, 75% in COD and 63.69% in TSS.

8.4 Oxidation Pond

a) In the Fatehgarh STP of 2.7 MLD capacity, situated in FARRUKHABAD, the in-situ sewage treatment technology adopted involves primary oxidation ponds (2 in number) each of dimension 100m × 150m × 1.2 m, followed by secondary oxidation pond. The treated effluent is discharged into river Ganga. As per analysis report, the STP was found non-complying w.r.t general discharge standards for pH, BOD and TSS. However, BOD and COD showed a reduction of 53.98% and 34.95% respectively while ammonical nitrogen and phosphate levels reduced by 95.1% and 97.36% respectively.

b) In the 6 MLD capacity STP at Baidyabati in West Bengal, there are a total of three lagoons in series for treatment of sewage before maturation pond. The analysis of treated sample indicated BOD and COD reduction of 78.57% and 27.3% respectively. However, during inspection by CPCB officials, it was observed lagoons are eutrophicated while baffle walls and embankment are partially damaged.

9.0 AN EXAMPLE OF PROPOSED TREATMENT SCHEME

A typical first order drain having flow of 500 MLD with physical characteristics like length – 20 km, width of drain varying between 30-90 meter and organic loading of 100-250 mg/l of BOD may adopt *in-situ* constructed wetland system with horizontal and free-flowing system. This system will have two oxidation ponds, two physical treatment units and a constructed wetland.

The two oxidation units of 100 m long each are separated by three gabions; the two physical treatment units of 75 m long each and have vertical channels separated by gabions. The constructed wetland is of 150 m length and has 15 furrows of 8 m width, separated by 15 ridges of 2 m width. The schematic layout of the proposed constructed wetland is given in figure-21. Depending upon the width of the drain, the number of vertical channels varies and also length and height of gabions varies from site to site. Further design details of each unit are mentioned below:

1. Oxidation Pond:

   Depth: Gabions of 4m width with height of 2.5 meter;

   Width: As per availability (15-90 meter)

   Length: 100 meter

   Number of Oxidation Pond: 02

2. Physical Filters:

Vertical channels: Width upto 8 meter, height 1-5 meter, length 75-100 meter and number of channels varies as per width of drain

Depth: Gabions of 2m width with height of 1.5 meter;

Number of Physical Filters: 02

3. Constructed Wetland Systems

   Depth: Gabions of 2m width with height of 1.5 meter;

   Length- 150 m long

   15 furrows of 8 m wide separated by 15 ridges of 2 m wide

Actual design may vary as per available physical characteristics and organic loading of drain

- Expected Outcome

  BOD removal: 50-70 % reduction

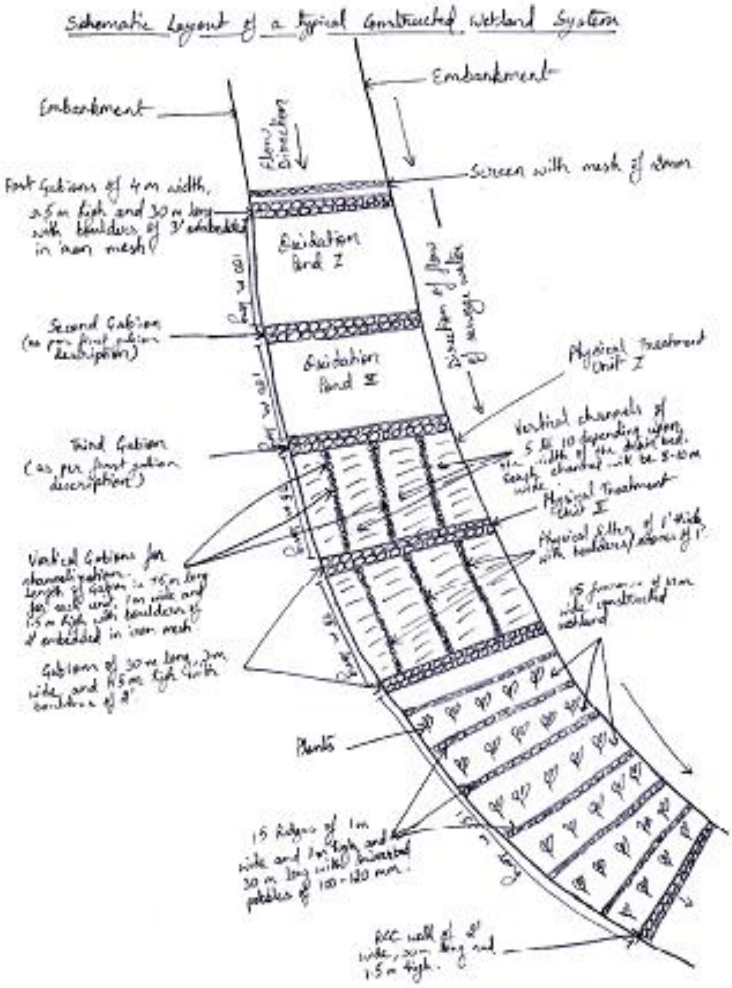

Figure 21: Schematic diagram of In-situ Remediation

9. ACKNOWLEDGEMENT

Inputs provided in the preparation of models alternate biological treatment techniques for drains by Prof.C.R. Babu, Professor Emeritus, Centre for Environmental Management of Degraded Ecosystem, University of Delhi, Prof. P. K. Mishra, Head, Department of Chemical Engineering & Technology, IIT-BHU, Varanasi; Prof. S.N. Upadhyay, Ex Director, IIT-BHU, Varanasi and Prof. C.B. Majumdar, Head, Department of Chemical Engineering, IIT Roorkee are acknowledged.

ANNEXURE-I

DESIGN AND PERFORMANCE DETAIL OF EX-SITU TREATMENT TECHNOLOGY

Design Criteria

- **Requirement of Physical Characteristic of Drainage System**

Length of drain : 2-20 Km

Width of drain : 2-15 m

Depth of flowing water : 0.5 2 m

- **Organic Loading**

BOD : 100-250 mg/l

COD : 150-500 mg/l

- **Hydraulic Loading**

Flow : 2-20 MLD

Volumetric loading : 100-400 BOD g/m3.day

Typical characteristics of different types of Ex-Situ treatment technologies for treating domestic sewage are mentioned in table below:

SL. No	Characteristic	Facultative type Lagoon	Aerobic flow through type Lagoon	Aerobic with solids recycling Lagoon	Oxidation Pond
1.	Suspended solids concentration , mg/l	50-150	100-350	3000-5000	-
2.	Sludge age or mean cell residence time , days	High (because of settlement)	Generally 5	Warm:10-20 Temperate:20-30 Cold: over 30	-
3.	Overall BOD removal rate K_L per day at 20 ^{0} C	0.6-0.8	1-1.5	20-30	-
4.	Temperature coefficient,	1.035	1.035	1.01-1.05	
5.	Detention time, days	3-12	Generally 5	0.5-2	7-15 days
6.	BOD removal efficiency, %	70-90	50-60	95-98	80-90%
7.	Nitrification	None	Non favorable conditions	Likely under	-
8.	Coliform removal, %	60-99	60-90	60-90	99%
9.	Depth, m	2.5-5	2.5-5	2.5-5	1-1.5 m
10.	Land requirement, m^2/MLD	2200	2200	1111	8800
11.	Power requirement,	12-15	12-14	18-24	-

SL. No	Characteristic	Facultative type Lagoon	Aerobic flow through type Lagoon	Aerobic with solids recycling Lagoon	Oxidation Pond
	KW/Person -year				
12.	Minimum power level, KW/1000 m^3 lagoon volume	0.75-1	2.75-5	15-18	-
13.	Sludge	Accumulates in lagoon; manual removal after some years	No accumulation; solids go out with effluent	Surplus sludge withdrawn continuously (daily) and disposed off suitably	Accumulates in Oxidation Pond; manual removal after some years
14.	Outlet management	Effluent flows over a weir	Partially or fully submerged pipe outlet	Weir or pipe	Weir or pipe