In-Situ Bioremediation for Treatment of Sewage carrying Drains Joining River Ganga –Performance Evaluation of Technologies and Development of Guidelines and Protocols

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Summary

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1.0 INTRODUCTION:

It is a well known fact that cities/towns in the country do not have facilities for treatment and disposal of sewage. Class I and Class II cities, altogether generate 38,255 MLD of sewage and treatment facility is available only for 11, 787 MLD leaving a gap of 26,468 MLD (69%). This situation is resulting to water pollution in the recipient water bodies. In view of prevailing situation and considering magnitude of sewage pollution, Central Pollution Control Board (CPCB) proposes to launch 'In-situ sewage treatment with bioremediation technology; a scheme which is relatively cost-effective and offers simpler solution for Municipalities.

2.0 IN-SITU TREATMENT TECHNOLOGY:

In-situ Bioremediation refers to "Treatment of sewage in the running battery of flow without displacing; and by employing microbial consortia in aerobic and facultative environment to degrade sewage resulting into CO_2 and H_2O and reduce odour".

In-situ treatment (IST) is simple and easy-to-operate and does not require major modification of the drain. Naturally occurring Microbial consortia is used in the treatment process or activated to degrade sewage in flowing conditions without diverting the flow and no additional requirement of land or Power is involved. The technology is considered to be cost-effective, relatively cheaper than conventional treatment methods, easy to handle, not requiring skilled man-power to operate.In the process, the microbes are activated and allowed to multiply by adding or extra-cellular enzymesin presence of oxygen and available food in form of organic matter and sewage degradationtakes place. During the inoculation period, intensive dosing is done in the site and after stabilization of the treatment, normal dosing is applied. The microbial dosing is done as per requirement assessed in terms of organic pollutants (microbial food) content in sewage. The activated microbes consume organic mass and

utilize the nutrients from the water body for their growth and multiplication; thus enhance the cleaning action of wastewater. The anaerobic as well as facultative bacteria play a vital role in treatment of sewage without causing any release of foul odour. In the process of treatment pollutants in terms of BOD, COD, TSS, TDS, heavy metals and toxic chemicals are reduced. Due to the action of the dominant microbial consortia, the harmful pathogenic bacteria like E.coli, etc are suppressed or eliminated from the treated water. In India, the technology has been demonstrated in Delhi (MayurVihar Drain), Pune (BhosariNalla) and at Udaipur (Ahar River). The outcome/findings of these bioremediation projects were found to be encouraging.

3.0 OBJECTIVES OF IST:

(i) Demonstrate In-situ Treatment of Sewage

(ii) Standardize the technology for replication in other drains.

(iii) Create awareness on the technology for prevention of water pollution particularly for rivers.

(iv) Impart training to the concern staff for implementation of In-situ Bioremediation of sewage.

4.0 The Ministry of Environment and Forests on the proposal of Central Pollution Control Board has accorded Administrative Approval and Expenditure Sanction for demonstrating In-situ Bioremediation for Treatment of Sewage carrying drains. The demonstration is proposed for the drains joining river Ganga at Farrukhabad, Allahabad and Patna. The drain joining river Satluj at Ludhiana has also been taken up for demonstration.

5.0 CPCB in pursuance to the decision taken in the Fourth meeting of Research Advisory Committee held on 28th February, 2011 has suggested that an integrated proposal be formulated by CPCB on research aspects of bioremediation for RAC's consideration. Such comprehensive proposal should address and incorporate different issue related to optimization of the process of technology, design parameters, reliability and replicability.

6.0 Keeping in view CPCB has formulated the proposal and the proposed project relates to R & D aspects of in-situ bioremediation and organising training and mass awareness programmes in the concerned states. The R & D components include;

(i) Standardization of the design parameters of In-situ sewage treatment technology in terms of working methodology, microbial dosing, and working optimum ranges of pH, temperature, time, hydraulics, etc.

(ii) Evolving Protocol and guidelines for implementation in other parts of the country.

(iii) Assessing efficacy and effectiveness of each treatment process with regard to removal of pollutants and elimination of pathogens.

(iv) Developing treatment packages with microbial dosing Vs MLD of sewage to be treated and taking care of microbial population control.

(v) To examine the environmental consequences on long-term basis.

(vi) Listing of microbes used in consortia so to rule-out 'secrets' and having no doubts on harmful microbs.

(vii) Study the formulation of intermediary compounds for assessing complete degradation.

(viii) Studying inhibitory/ antagonistic parameters effecting in-situ treatment.

7.0 For project investigation, elaborate monitoring design and the relevant parameters (physico-chemical and biological) are selected. A statement indicating sampling schedule and analytical pattern is as under;

S. No.	Parameters to be monitored	Sampling frequency for per Centre	Months per Centre	Total Samples	Total samples at 4 Centre
1	Flow, Temperature, pH, Oil and Grease, BOD, COD, NO_3, NH_3-N, PO_4-P	Weekly Fort-nightly monthly	3 3 6	12 6 6	48 24 24
			12	**24**	**96**
2	Heavy Metals and Pesticides	Fort-nightly Monthly	3 9	6 9	24 36
			12	**15**	**60**
3	Bacteriology (FC, E.coli, Streptococcus, Salmonella, Shigella, Vibrio, Pseudomonas)	Weekly Fort-nightly Monthly	3 3 6	12 6 6	48 24 24
			12	**24**	**96**

IN-SITU SEWAGE TREATMENT THROUGH BIOREMEDIATION PROCESSES – PROPOSAL FOR DEMONSTRATION

1.0 IN-SITU SEWAGE TREATMENT(IST) - CONCEPT

In view of prevailing big gap between sewage generation (38,255 mld) and treatment, (11,787 mld) CPCB has proposed to work on application of 'In-situ sewage treatment with bioremediation technology' which is relatively cost-effective and offers simpler solution to Municipalities.

In-situ treatment (IST) in drain does not envisage any major modification of the drain. Such treatment is simple and easy-to-operate. Microbial consortia used in the treatment, degrade sewage in flowing conditions without diverting the flow and no additional requirement of land or electrical Power. Cost-effective and the bioremediation of sewage is accomplished with consortia of beneficial bacteria isolated from the native site. The consortia of beneficial bacteria are cultured in bulk and applied to the flowing sewage for further treatment. In Initial process, the microbes are activated and multiply in presence or absence of oxygen as applicable, and food available in form of organic matter present in sewage. During the inoculation period, intensive dosing is done and after stabilization of the treatment, normal dosing is applied. The microbial dosing is done as per requirement assessed in terms of organic content of sewage (i.e. BOD). The activated microbes consume organic mass and utilize the nutrients from sewage for their growth and multiplication and thus enhances the cleaning action of wastewater. The anaerobic as well as facultative bacteria play a vital role in treatment of sewage without causing any release of foul odour. In the process of treatment, pollutants like BOD, COD, TSS, TDS, heavy metals and toxic chemicals are reduced. Due to the action of dominant microbial consortia, the harmful pathogenic bacteria like E.coli, etc are suppressed or eliminated from the treated waste water.

As planned, throughout the country, storm water drains were designed for disposing runoff/ or draining storm water out of city/ town during rainy season to avoid the floods. Due to lack of sewerage system, domestic wastewater is discharged into these open storm water drains. Thus, these drains have been converted into sewage carrying drains. The human population residing along or nearby such drains are

exposed to the filthy odor, and unhygienic environment and besides becoming potential threat to contaminate groundwater.

The existing sewage treatment plants are based on conventional systems which involves high construction cost, and skilled operation and maintenance. With this view, CPCB mooted a concept of “in-situ sewage treatment”. The concept is based on microbial treatment of sewage flowing in drains through various techniques. The conversion of this concept into technology is considered to be cost-effective as compared to conventional treatment and easy to handle, not requiring skilled man-power and low or no electrical power requirement to operate the treatment processes. The in-situ sewage treatment takes place while flowing in open drains without displacement of sewage thereby requiring no additional space for treatment. The technology does not involve chemical dozing and instead microbial consortia are used for dozing which are primarily of native origin and thus, not causing any hazards to environment or mankind.

The in-situ bioremediation is accomplished with external dosing of microbes in running sewage. The employed microbial consortia are not genetically modified and are certified by the concerned agency. These microbial consortia already exists in the nature and they are to be activated by providing suitable environmental conditions for multiplication so to treat the waste water. At times, enzymes are added for activating the microbes. It is important feature of the bioremediation that the microbial consortia remains active in given conditions like aerobic, anaerobic and facultative environment.

2.0 IST TECHNOLOGIES

The methodology of in-situ bioremediation involves pre-requisite of cleaning of drain, setting up of dosing facilities at pre-selected points, installation of barriers for effective mixing of doses, flow regulation, pollutant absorbing aquatic media and plants and other naturally available materials. In the process, a selected stretch of the drain is inoculated with the microbial consortia, where the organic material of sewage serves as food for the microbes and other chemicals nutrient are used for their metabolic system. The organic pollutants like BOD, COD, SS and other chemical radicals are reduced up to 60-80% and toxic elements and heavy metals are reduced up to 40-60%.

The Bioremediation technology has been used in several countries and its application has been confined to lakes and reservoirs. In India, the technology has been demonstrated at Delhi, Pune and in Rajasthan. Outcome and findings of these projects were found to be encouraging.

3.0 DEMONSTRATION OF IST TECHNOLOGIES

The various techniques of bioremediation adopted by individual firms for demonstration of river Ganga including at Ludhiana for Budha Nala are summarized as under;

3.1 Morigate Nala, AllahabadM/s Amrit Clean Water technologies has been identified for demonstrating "In-situ Treatment of Sewage" for Morigate Nala, Allahabad (UP). The Firm will be exhibiting patented "Emtech" technology. The technology involves bio-augmentation of microbial consortia known to be occurring naturally. The 'Class–I' referred bacteria do have US Quality Control and available in Library-Bacteria. 'Emtech' product is a blend of aerobic and facultative bacteria to work in low level oxygen environment and enhance degradation of organic matter, reduces carbohydrate, and fats. The minimum retention time required for food-microbe interface is 10 minutes. The Firm has working experience in Thailand and Delhi holding pond of Qutab Golf Course.

3.2 Bakarganj Nala, Patna

M/s US Environ, New Delhi will to demonstrate in-situ treatment Bakarganj Nala, Patna (Bihar). The Eco Bio Block (EBB) technology being practiced by the firm has already been demonstrated abroad (Japan and Malaysia) as well as in India (Mayur Vihar drain, Delhi). The EBB is manufactured by volcanic rock and other marine – materials, serves as houses for micro-organisms that provide supportive structure. The EBB structures have 3 models of placement for effective contact with running water. The technology also works at minimum temperature of 10^0C. Treatment efficiency is assessed for the removal of is BOD 99.8%, COD 97.9% and TSS 99%.

3.3 City Drain, Farrukhabad

M/s Clover Organic Pvt. Ltd., Dehradun will exhibit technology based City(Hathikhana) Drain at Farrukhabad, (UP) on bio-augmentation and self–cleansing and bio-mimicry concept. The fermented mud balls, gravel dykes and charcoal with net are used for treatment of water courses with locally available

materials. The technology is developed to utilize naturally available materials. M/s Clover Organic has proposed to work with IIT, Kanpur for undertaking performance studies on in-situ treatment facility at Farrukhabad.

3.4 Budha Nala, Ludhiana

M/s Green Infrastructure, Pune will be demonstrating bioremediation of Budha Nala at Ludhiana (Punjab) by employing its own patented 'Green Bridge' technology. The proposed technology enhances natural treatment of water and soil resulting in increase in diversity of aquatic lives. The projects at smaller level have been demonstrated Mula-Mutha River at Pune and at Udaisagar lake-Ahar river, Udaipur. for cleaning water bodies and has achieved BOD/ COD reduction up to 70%. The cost of treatment varies from Rs. 1.0 lakh to Rs. 10.0 lakh per MLD depending upon its hydraulic load and pollution load. Further, one-time cost investment is involved for the Green Bridge.

4.0 ASSESSMENT OF TECHNOLOGIES

In-situ Bioremediation of sewage implies application of microbial consortia and biological reactions are hasten by incorporating minor changes in drain by placing locally available materials like boulders, bricks, aquatic plants, charcoal, etc. The consortia of microbes do naturally exist in the local environment and these are either activated through addition of enzymes and supplemented/ enriched with additional microflora to treat the sewage effluents and/ feed upon organic matter. Microbial consortia utilize sewage matter in their metabolic system as food/ substrate. In favorable condition, microbes multiply almost double in every 20 minutes and thus, further supplementation is not required in lotic stage. The microbial waste water treatment can restore water quality and increases self cleansing capacity of water body. The bioremediation process facilitate in reducing BOD, COD, TSS, Coliform in sewage water and also reduces odour problems.

The microbial dosing is generally done in running water and contact is created by providing barriers of stone/boulders or baffled wall made of bricks, which also helps in uniform mixing of doses. The barrier also makes turbulence thereby creating oxygenation and provides substratum for microbes. The hydraulic cells created by barriers helps in treating water step by step with various doses as per requirement. The selected aquatic plants are also grown separately on the barriers/banks which

helps in absorbing pollutants and creating an ecosystem in the water body. The sludge accumulated in the process is taken care by another group of organisms (anaerobic). Generally, provisions are made against siltation and debris accumulation in the system and are removed periodically.

4.1 Life Cycle Assessment

At the initial and project conception stage, CPCB received expression of interest from 7 Firms. Out of 7 Firms, four firms have been chosen to demonstrate their technology for the drains joining river Ganga. The selected locations are Farrukhabad, Allahabad, Patna and Kolkata. However, the proposal for Kolkata is yet to be received because the drain selected earlier has been closed by Kolkata metro rail. At Ludhiana, the Budha Nala has been selected for demonstrating in-situ bioremediation technology at a magnified level where the flow of sewage around 600 mld.

The concept of treatment is common in all the technologies which is based on application of microbial consortia and supplementation with extra cellular enzyme to create conducive conditions for bioremediation.

Presently, four demonstration projects of in-situ bioremediation have been administratively approved by the Ministry for locations at Farrukhabad, Allahabad, Patna and Ludhiana. Each technology in these cases is different and unique which is varying because of application of combination of different microbial consortia. In some cases the bioremediation process is based on in-situ inoculation and in other cases, it includes inoculation and creating minor physical intervention within the drain. The comparative assessment/ striking features of offered technology are as under;

S. No.	Firm	Technology	Principle of operating technology	Targeted reductions
1	M/s Green Infrastructure	Green bridge patented technology with unit process for horizontal filteration system to treat water flowing in any size of any type stream(CBR no. 22005, April3,2006)	Waste water after screening is allowed to pass through a barrier of biological filter and supplemented with nutrients. Embankments of the drain are planted to uptake nutrients. The entire technology is based on bio-film and are constructed wetlands.	Reductions will be achieved less than 30 mg/l for total suspended solids (from original concentration ranging 200-400 mg/l in Budha Nala), less than 150mg/l for Chemical Oxygen Demand (COD) (from original concentration ranging 350-550 mg/l in Budha Nala), BOD less than 30 mg/l (from original concentration ranging 60-200 mg/l) and 99% reduction of fecal coliforms (from 10^8-10^9 MPN/100ml)

<table>
<tr><th>S. No.</th><th>Firm</th><th>Technology</th><th>Principle of operating technology</th><th>Targeted reductions</th></tr>
<tr><td>2</td><td>M/s Clover Organic Pvt. Ltd.</td><td>Mimicking –self cleansing</td><td>Based on bio-mimicry utilizing kinetic bio-degradation. Technology operated based on adsorption and degradation, aeration, filtration and sedimentation</td><td>Will achieve the quality of treated sewage effluents that BOD will be <30mg/l, COD <150 mg/l and fecal coliform will meet standard(500-2500 MPN/100 ml)</td></tr>
<tr><td>3</td><td>M/s Amrit Clean Water Technologies Pvt. Ltd.</td><td>“Emtech-selective microbial consortia”</td><td>Technology allows co-existence of different strains of microbes blended together without outcompeting each other, their by withholding the effects. The Technology adopted is bio-augmentation i.e, addition of select bacteria in the treatment area to increase the beneficial count and thus encouraging faster degradation of organic matter.</td><td>Will achieve the quality of treated sewage effluents as per inland surface water standards so to achieve BOD=<30mg/l, COD=<250 mg/l, SS=<100mg/l and fecal coliform in the range of 500-2500 MPN/ 100ml</td></tr>
<tr><td>4</td><td>M/s US Enviro</td><td>Eco - Bio Block technology (EBB) (patent no. US, 989, 266B2/Jan.24,2006)</td><td>EBB treatment is a technology with “back-to basic” concept of using environmentally friendly micro-organism embedded in a porus concurred block to waste water. EBB is a product made of porus volcanic rock, cement, beneficial bacteria and nutrients that are released regularly upon immersion in water.</td><td>“M/s US Enviro has communicated that they will be achieving the following outcome after the treatment which are as follows;
<table>
<tr><th>Parameter</th><th>Sample Wastewater</th><th>Results assured After Treatment</th></tr>
<tr><td>BOD</td><td>110 mg/l</td><td>50 mg/l</td></tr>
<tr><td>COD</td><td>240 mg/l</td><td>110 mg/l</td></tr>
<tr><td>TSS</td><td>326 mg/l</td><td>130 mg/l</td></tr>
<tr><td>Fecal Coliform</td><td>> 5000</td><td>50-55%</td></tr>
</table></td></tr>
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4.2 Operation and Maintenance

All the four technologies selected for demonstration are cost-effective as compared to sewage treatment plants. The major cost of in-situ technology involves procurement of microbial culture which is the basic need. In a few cases, the initial cost is on creating physical structures. The operation maintenance is relatively easy and does not require skilled operations.

A comparison of in-situ treatment technology versus conventional treatment plants is given below;

	Parameters / Features	In-situ sewage treatment	Conventional STP
	Concept	In-situ bioremediation refers to using of microbes	Ex-situ bioremediation using microbes
	Microbes	Microbial consortia (aerobic, anaerobic and facultative)	Microbes - Aerobic and facultative

	Parameters / Features	In-situ sewage treatment	Conventional STP
	Treatment units / Civil structure	Nil or very less	Complete unit required and need land allocation
	Power consumption	Nil or very less if mechanical devices used	Electricity required all the time for aerobic treatment, pumping but, oxidation ponds may not require electricity (excluding pumping)
	Operational skill	Skilled operators not required	Required
	Construction cost	Nil/ insignificant	Significant
	Performance efficiency	Provide pre-stabilization and helps in reducing polluting loads being directly exerted by sewage drains. Achievement may not be 100% in-terms of pollution reduction but, since providing at least 50% reduction without much cost and hence needs to be adopted.	Although, percent reduction are higher but failure in power/ break down/ unskilled operations yields zero result.
	Operation and maintenance	Very less and requires for microbial dosing.	Regular O & M is must and requires recurrent expenditure

5.0 PERFORMANCE GUARANTEE

Implementation of technologies based on the concept of in-situ bioremediation is almost new in the country. The experiments conducted elsewhere are not either commercial or bearing any R & D component in it. Without putting such technologies widely in practice, aiming for high performance and getting best results at-once, will take same time. However, once such technologies are demonstrated and by virtue of experience, the desired results and compliance with existing standards can be assured. The four participating firms have made their commitment to achieve the possible reductions. Each firm unless demonstrate best results, they cannot compete at national level when such concept is propagated for implementation.

In all the in-situ technologies no royalty/ Patent charges are claimed by any of the Firm. However, CPCB has asked all the four Firms to provide bank Guarantee for achieving claimed performance of their technology which will be in-terms of BOD, COD, TSS and coliform bacteria. This BG will be 5% of the overall cost of the project.

6.0 MONITORING AND THIRD PARTY ASSESSMENT

Since, for the first time, in-situ bioremediation technologies are being demonstrated, at a large scale, CPCB itself would undertake monitoring of the four projects. The monitoring would include technical assessment as well as R & D component involved in it. However, at later stage, the institutions like IITs/ NEERI, etc. could be involved as third party inspection agencies when these technologies are okayed by CPCB for their wider application at national level.

7.0 DRAINS AND CLAIMED PERFORMANCE

7.1 Drains Selected For Demonstration

Drains	Flow (MLD)	Characterization	Disposal
Budha Nala (Punjab)	600	BOD: 60-200 mg/l COD: 350-650mg/l SS: 200-400 mg/l FC: 10^{8-} 10^{9} MPN/100ml	River Sutlej
Morigate Nala (UP)	40	BOD: 96- 138 mg/l COD: 280- 348 mg/l SS: 188- 239 mg/l pH: 7.43 DO: 0.7 mg/l	River Ganga
Bakarganj Nala (Bihar)	21	BOD: 110 mg/l COD: 240 mg/l SS: 326 mg/l FC: 72400 MPN/100ml	River Ganga
Farrukhabad (UP)	16	BOD: 105 mg/l COD: 161 mg/l TSS: 74 mg/l FC: 1.5 $X10^{6}$ MPN/100ml	River Ganga

7.2 Demonstration of Technology and Performance

Drains	Technology	Project Cost	Expected results
Budha Nala	Green Bridge - microbial and plants	Rs. 15.28 Crore	BOD: <30 mg/l COD: < 150 mg/l TSS: < 80 mg/l FC : 90% reduction

Drains	Technology	Project Cost	Expected results
Morigate Nala	Inoculation –slow release of microbial consortia (Tablets/Blocks)	Rs. 1.38 Crore	BOD: < 30 mg/l COD: < 250 mg/l TSS: < 100 mg/l
Bakarganj Nala	Microbes embedded in porous blocks (Eco-Bio-Blocks)	Rs. 2.24 Crore	BOD: 50 mg/l COD: 100 mg/l SS: 130 mg/l DO:: 0.5 mg/l FC: 55% reduction
Farrukhabad Drain	Physical/Biological-Bio-Mimicry (Self purification capacity of river)	Rs. 0.94 Crore	BOD: <30 mg/l COD: < 100mg/l TSS: < 100 mg/l FC: <1000 MPN