CLEANING UP DRAINS AND RIVERS THROUGH BIO-MIMICRY

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ABSTRACT:

Nature as we know is perfect. It gained this perfection after 3.8 billion years, what we call evolution. Bio-mimicry is a new Science, which has emerged in the last 10 years or so. The Science is based on mimicking design and process ideas from nature. Many solutions have come out around the world, which is based on inspiration from Nature.
A system of cleaning up large or small drains and rivers has been designed and conceptualized based on Nature's way of cleaning up contaminated water. The system uses a three-tiered process of bio-remediation, phyto-remediation and bio-mimicry to ensure that proper cleaning takes place without the use of any energy, creating any major infrastructure and negligible running cost. Hardly any repair or maintenance is needed. The system also promises to reduce sludge accumulated near rivers/drains, re-growth of native grasses and restoring the eco-system. The process is as follows:A simple design will be used to mimic the self-cleansing process of rivers – Filtration, Aeration, Sedimentation and Adsorption, natural and non-GM microbes will be used to create 'river or drain bank cleaners' along with innovatively introduce them into the drain or river so that they do not get swept away by the force of the flow, very selective plants will be used on the banks to reduce BOD, COD, and Faecal Coliform count and at the same time increase DO levels.The system is ideal for areas where conventional technologies cannot be used owing to logistics or financial concerns. We are confident that once this system, could cause a transformation in mitigating pollution in the Country's water resources, which today is being indiscriminately polluted.

1. INTRODUCTION:

The storm water drains in India are being used by the residents more for carrying sewerage than storm water. This is leading to all sorts of problems like emission of foul odour, generation of vectors like mosquitoes and flies, blockage of drains leading to floods during a heavy down pour etc. Perhaps the biggest victim of this form of pollution are the natural resources like rivers. They get contaminated resulting in amplifying the problem further. Apart from imparting a bad aesthetic look to the total sewage system the air that comes in contact with the sewage system contains a variety of odorous compounds out of which Hydrogen sulfide smell is the one to be noticed first because of its masking ability over other odors.

The power to harness various enzymatic pathways coded by the microbes for the bioremediation purposes is well documented in literature. Recent genome sequence completion of various microbes has shed light on interesting microbial products and indicated towards ways and means of using those genomes for amelioration of polluted environment. It is also known now that microbial action is enhanced when used in the form of consortia rather than isolated monoclonal cultures. It means, a cocktail of carefully chosen microbes will perform in a complex ecosystem better than a single form.

Bio-mimicry (1)is an emerging discipline that studies nature's designs and processes to solve human problems.
Many products have already been designed on the nature's design (2) and processes. Some of these are as follows:

a. The design for the rotor blades of the wind mills have been mimicked from the wings of the dragon fly so that they move even at zero wind velocity.
b. The bullet train in Japan was designed on the aerodynamic shape of the king fisher bird. This led to a 20% increase in velocity while saving 15% fuel approximately and a large noise reduction while moving.
c. Paint was designed by STO in the US, which mimics the self cleansing process of the lotus leaf by creating ridges on the wall. Rainwater hits the walls and carried away the dirt.
d. Volvo car Company has placed a sensor on the car circuitry, which mimics the locust. It warns the driver of any near by obstacle, there by minimizing car crashes.

If we look at how nature cleans its waste, then we find that nature uses the following:

a. Various Designs to break down organic matter.
b. Plants (Phyto-remediation)
c. Microbes (Bio-remediation)

If we study the different ways nature cleans its waste, then it may become possible to clean up large water bodies like rivers, drains, lakes etc

Clover Organic Pvt. Ltd has studied the self-cleansing system of rivers and have come up with a solution, which we feel will work. We have been given an opportunity to carry out a pilot by MoEF, which shall be underway soon in UP. We have planned this pilot in such a way that once successful; it can be replicated across the Country. The expertise of environmental engineering and biotechnological field will greatly aid us in ensuring that wastewater is cleaned at minimal cost, time and effort.

2. **THE CLOVER SOLUTION:** The solution conceived is as follows:

I. Objectives: The objective of the solution designed are to:

a. Treat flowing wastewater in drains or rivers without any infrastructural changes.
b. Suppress foul odour and vector population.
c. Offer the most cost-effective solutions.
d. To develop the technology in such a manner that the intervention should be simple and replicable across a wide geographical area.

II. Benefits of Clover model: We have formulized a system of cleaning wastewater in-situ by mimicking the self-cleansing process of the rivers(3). The benefit of this system are as follows:

a. It allows efficient treatment of wastewater without any infrastructure changes to the drain.
b. It helps to suppress foul odour and vector population.
c. The model is extremely cost-economic.
d. The model can be replicable anywhere provided that the drains and rivers fall within the parameters given in point no 6 below.
e. The system can theoretically work at a depth of up to 5-6 feet of water very easily.
f. In case of shock loads due to rains, the model allows excess water to be cleaned up to about 20% of the original flow.

III. Parameters to be kept in mind while implementing the model: The following parameters would need to be kept in mind while implementing this model. This also answers the queries raised in your letter:

a. **Depth:** The depth of the water should not exceed 5 feet on an average or during the non-monsoon period.
b. **De-silting requirement:** Though the model promises to clean up a drain without de-silting, we still suggest that the same be done so that effectiveness of the model can be accurately measured.
c. Quality of wastewater: In storm water drains, ideally like to ensure that only raw sewage has to be dealt with and there are no Industrial effluents in the drain.
d. Physical working conditions: The parameters where we find that the model works best are as follows:

- **Temperature:** Mesophillic ideally though it would work in most temperature conditions.
- **Retention Time:**No retention time is needed as the system shall work in-situ.
- **Flow:** As this model essentially mimics the river, we can handle any volume of flow.

e. Space required around the drain: For operational reasons, the model requires a space of about 2-3 meters on either side of the drain for most efficient treatment. This will allow for creating ‘drain or

river banks' or 'water scrubbers' and some space for equipment and movement for inspection if needed.

f. Sustainability during rainy/ flood conditions: The system has been designed in such a way that it would work in any season, just like normal rivers do! The excess water would flow over the boulders and not damage the system. All the four mechanisms will still work. The efficiency levels might go down, but it would be ore than compensated by the high dilution of the pollution with rain-water. Hence, pollution would still be mitigated.

g. Prevention against mosquito breeding at check-dams/ stagnant water: This is possibly the biggest problem being faced in India. We have taken reduction of foul odour and vector as a tangible objective in this project. The different ways we will arrest breeding of mosquitoes and flies would be as follows:

- Vectors breed in still waters. The flow of the drain or river gets blocked due to solid waste being dumped into it, water getting arrested on the banks of the drain due to excess sludge generation or near the check dams.
- Attempts would be made to mitigate throwing of solid waste into the drains and river bodies by educating the community. Solid Waste Management (SWM) would take place separately near the drains through simple heap method.
- As stated earlier, NatureVel – WW would be sprayed on the banks of the drain. This would lead to reduction in sludge to a large extent thereby ensuring stagnancy in water does not arise.
- The check dams in the form of boulders made by us would be highly porous and would always allow the flow to take place.

h. Maximum and Minimum time required for performance evaluation: Going by the past studies conducted, we know that the maximum time for the pilot to be successful should not exceed 12 months and minimum time would be at least 6 months. This is based on the bio-augmentation reports received from several STPs treated by Clover as well.

i. Quality/ quantity of sludge generated and its mode of disposal: Through this model, especially designed to mitigate pollution, hardly any sludge will be generated over a period of time. This would be due to the following reasons:

a. The sludge would settle and get eaten away through the process of sedimentation and adsorption on the boulders and gravel. The microbes in NatureVel – WW would help to convert it into CO_2 and H_2O.
b. The spraying that would take place on the banks of the drains would further reduce sludge drastically.

IV. Strategies to clean the drain: Several strategies would be used together in a parallel fashion to ensure that in-situ treatment of drain is carried out efficiently (4). These would be as follows:

a. **Bio-mimicry:** Along about 1 km stretch of the drain/river, we shall be designing an 'environment' that shall mimic the 'Self Cleansing Process of rivers'. This environment would be either made up of boulders and gravel or of some other material. The idea would be to bring out the 4 different ways a river cleans itself as mentioned in point No V below.

b. **Bio-remediation:** We shall further mitigate pollution with a special consortium of microbes called NatureVel – WW, that we are manufacturing in our own factory at Dehradun in collaboration with Biosa, Denmark. The process of bio-remediation shall however be carried out innovatively for maximum impact and to make up for no retention time available. This shall be done as follows:

i. **Dosing the drain:** Dosing the drain with NatureVel – WW, so that they enahance the cleaning process @ 1 liter per 10 KL of flowing water.

ii. **Creating 'Water Scrubbers':** The culture shall be sprayed on the river or drain banks. This shall not only reduce the accumulated sludge on the banks, but also help in cleaning water each time it comes in contact with the banks.
iii. **Charcoal Bags:** Charcoal bags charged with microbes act as filters and would be placed in strategic locations to force the wastewater to go through them, thereby carrying out bio-augmentation.
iv. **Fermented Mud Balls:** We would be making and placing fermented clay balls, that would be placed approximately @ 1 ball per sq. meter. These balls would sink to the bottom and not easily flow away due to their weight. These balls would contain billions of beneficial microbes, which would treat the drain/river from the bottom slowly over a period of time.

c. **Phyto-remediation:** Certain plants shall be chosen very carefully to draw out nutrients from the flowing water. We plan to plant simple plants like Kenna flowers or plant bamboos, to further reduce the pollution in the drain or rivers. This would also reduce the Coliform countin the wastewater.

V. Self-Cleansing Process Of River: The four processes of self-cleansing process of a river are as follows.

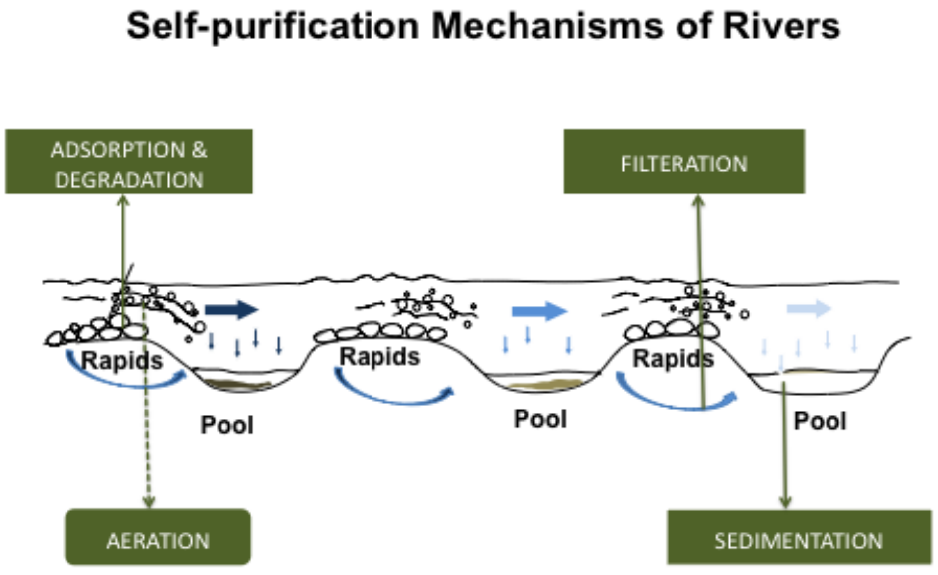
a. **Absorption and degradation**- In the river dirt is adsorbed onto bio-film formed on the surface of the gravel. This bio-film is generally algae. Some microorganisms like bacteriophages present in the water along with Benthos found in the river-bed, degrade harmful bacteria. Adsorption is the process of attraction of atoms or molecules from an adjacent gas or liquid to an exposed solid surface. Such attraction forces (adhesion or cohesion) align the molecules into layers ("films") onto the existent surface. Thus a river attracts the dirt to the rocks and then degrades it.

b. **Aeration**- Water aerated naturally by flowing over sandy or pebbly beds or rocky falls. The flowing rivers strikes boulders and gives rise to a lot of turbulence. This in turn creates aeration for the water to get cleaned.

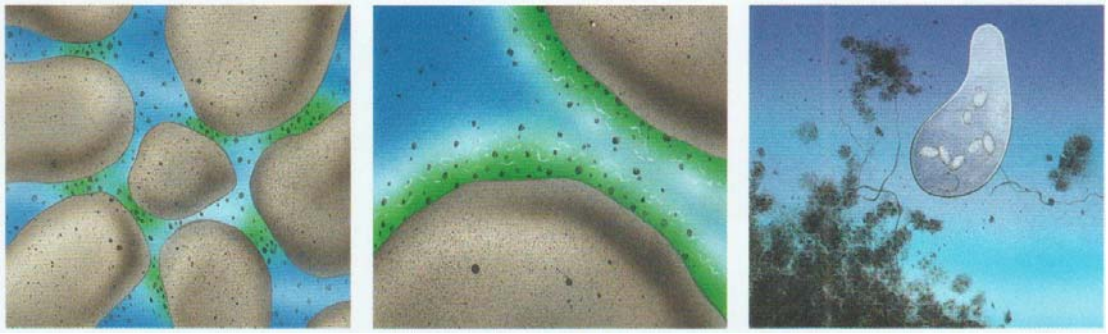
c. **Filtration**- Filtration is a mechanical or physical operation which is used for the separation of solids from fluids (liquids or gases) by interposing a medium through which only the fluid can pass. Oversize solids in the fluid are retained. River has large amount of gravel, pebble and silica on its bed and banks, which helps in the filtration of the river water.

d. **Sedimentation**- Sedimentation is the tendency for particles in suspension to settle out of the fluid in which they are entrained, and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them: these forces can be due to gravity, centrifugal acceleration or electromagnetism. Settling is the falling of suspended particles through the liquid, whereas sedimentation is the termination of the settling process. Trough and crests present in the bed of river helps the river water to sediment its impurity in flowing channel. Impurities also settle down on the banks of the rivers.

The parallel process that are at work in a flowing river are detailed below in Figure 1



The breakdown of organic load through the natural self-cleansing process of rivers is magnified below in Figure 2



1. Contact Sedimentation: When polluted water goes through gravel and charcoal, dirt in the water deposits on gravel and charcoal.

2. Absorption: Dirt is absorbed onto bio-film formed on the surface of gravel and charcoal (6)

3. Degradation: NatureVel – WW Microorganisms on gravel and charcoal decompose dirt into water and carbon dioxide.

VI. Creating Artificial River Like Environment To Mimic Its Self Cleansing Process:

a. **Absorption and Degradation**- In the drain or river, we would be using gravel and boulders, which would adsorb the dirt particles onto bio-film formed on the surface of it over a period of time(5). This process shall get further augmented by the addition of NatureVel – WW as already stated above.

b. **Aeration**- In order to increase the DO (Dissolved Oxygen) in wastewater, aeration is a must. In order to simulate the way River creates aeration, a mix of boulders, gravel and charcoal bags have been used. The wastewater would be forced to strike these 'obstructions', thereby create aeration.

c. **Filtration**- Natural 'filter media' in river systems are made up of a mix of gravel and sand. We plan to use a mixture of boulders and gravel to not only increase the surface area, but to also create natural filtration. The gravel size would be vary from 500m to 1000mm.

d. **Sedimentation**- The boulders will act as a barrier or a 'baffle wall' for the flowing water in drain and give time for impurities to settle. Boulders will also decrease the flow of drain water.

VII. Impact calculation:

The final calculation of impact on treatment shall be done using Streeter-Phelps model (8)(Streeter and Phelps, 1925; Nemerow, 1978). The Streeter-Phelps model ties together the two primary mechanisms governing dissolved oxygen in a stream receiving sewage, decomposition of organic matter and oxygen reaction. As such it provides an analytical framework for predicting the effect of both point and non-point sources of organic wastewater on stream and estuary dissolved oxygen. Streeter-Phelps model is founded on three principal formulas (Nemerow, 1978). The formulas to be used would be as follows:

1. $K_1 = (1/\triangle t) \log (L_A/L_B)$

2. $K_2 = K_1 (L/D) – (\triangle D/2.3\triangle tD)$

3. $D_t = (K_1 Ln)/(K_2-K_1)$

The upper equations permit to calculate de-oxygenation rate/day (K1), re-aeration rate/day (K2) and

dissolved oxygen deficit. We have chosen this model because it can be solved very easily by tradition integration methods.

VIII. NatureVel – WW Microbes to be used for inducing the self-cleansing process of rivers into the drains:

a. **The most advanced consortium of microbes:** We are manufacturing microbial products in collaboration with Biosa, Denmark. Though many bacterial cultures are available globally, NatureVel – WW is considered the most advanced as:

- It contains 10 different microbes as compared to just 3-4 in most microbial products.
- The plate count of these microbes is > 25 million cfu as compared to < 7 million cfu for other microbial products.
- Carefully selected herbs have been fermented into the product, which further assist in wastewater treatment in terms of foul odour and vector control and enzymes help in reducing the Coliform count as well (9).
- As a result of the above, the shelf life of the product is 12 months as compared to < 6 months for most microbial products.

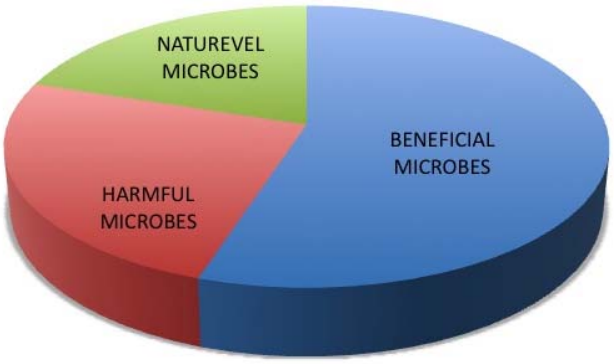
b. **Details of the microbes in NatureVel – WW are as follows**:

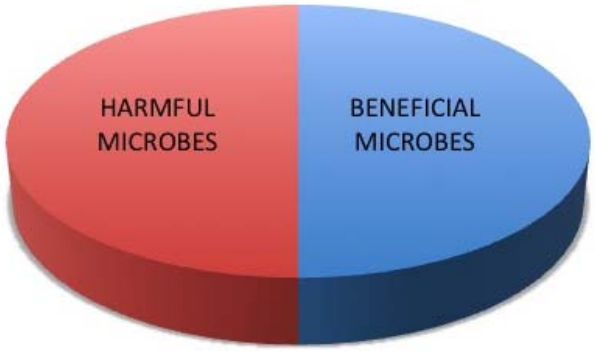
- **Lactobacillus Bacteria:** family Lactobacillaceae. Class: Lactobacillus acidophillus, Bifidobacterium animalis subsp. lactis, Streptococcus thermophilus, Lactobacillus casei, Lactococcus lactis subsp. lactis, Lactococcus lactis and subsp. lactis biov. diacetyllactis, Mainly used in food Industry.
- **Yeast Bacteria**: Saccharomyces palustris.
- **Photosynthetic bacteria:** Rhodopseudomonas palustris.

c. Key Benefits that NatureVel – WW offers for in-situ drain treatment are as follows:

- Meeting CPCB norms much more stringently in terms of BOD, COD, TSS, Coliform count (in sewage).
- It hardly requires any retention time – thus it is best suited to carry out in-situ wastewater treatment.
- Massive Sludge Reduction.
- It takes care of shock loads to some extent.
- Suppression of foul odour and vectors.
- Some drains have constantly changing influents. Their biomass is in constant flux. Adding NatureVel - WW helps to stabilize and increase the efficiency of the biomass.

Without Bioaugmentation **With Bioaugmentation**





d. Conceptual impact of bio-augmentation through NatureVel – WW on bacterial population in wastewater Treatment plants:

Degradation of the pollutants by bacteria is a complex process, which is termed self-purification (10). Degradation consists of a chemical change, which releases electro-chemical Energy. The released energy is used for building up energy rich organic phosphates (especially adenosine triphosphate) or (ATP), which in turn delivers energy for biomass synthesis (reproduction, growth) and for the maintenance of life functions (movement; replenishment of spontaneously degenerated protein molecules etc.). The energy consumption for the maintenance of life functions is described as endogenous respiration. In the creation of new biomass, the pollutants or by-products of their degradation possibly can be used as building materials (assimilation); but normally also other building materials, which cannot be derived from the energy donor, must be available in the water (e.g., nitrates, phosphates, and calcium). If an energy donor or some essential nutrient is not available, the endogenous respiration continues through the degradation of cellular matter (especially that of the reserve substance glycogen). That way the biomass is slowly reduced.

Every bacteria has the ability to decompose a certain nutrient; in most cases the degradation of that nutrient follows the same metabolic pathway. That is, while the nutrient is decomposed, the heterogeneous population acts like a homogeneous population. Those bacteria found in rivers show great flexibility in their use of the pollutants, that is, in the analysis of the self-purification processes one can be quite certain that the bacteria will react like a homogenous population in regard to most pollutants. These assumptions can be realized even when just a few species are able to degrade a substance, because often metabolic intermediates can be used by all bacteria. This is especially possible with the end products of reactions catalyzed by exo-enzymes (11). The simplest self-purification system consists of a homogeneous bacterial population in a completely mixed solution, which contains a single energy supplying substrate, as well as those inorganic substances necessary for bacterial growth.

The concept of NatureVel -WW is based on the inoculation of mixed cultures of beneficial microorganisms into the system where they shift the microbiological equilibrium. A series of inoculations are made to ensure that the introduced microorganisms continue their dominance over the indigenous populations. Unlike conventional technologies like the use of UV and chlorination, where reactionary treatment of unwanted pathogens is carried out, NatureVel – WW on the other hand, effectively cultivates beneficial microorganisms to a level where pathogenic, destructive bacteria cannot compete and therefore do not proliferate. This in turn reduces biological stress of purifying wastewater.

The exact mechanism of how NatureVel - WW acts and interacts in the microbial ecology is not known. However, there is evidence that supports a number of theories concerning the mechanism of action of NatureVel - WW. These include the suppression of pathogens and disease-causing microorganisms, conservation of energy, solubilization of minerals, microbial-ecological balance, photosynthetic efficiency, and biological nitrification. These microorganisms coexist and act synergistically when applied. They decompose organic compounds and produce various low-molecular organic compounds, such as amino acids, sugars, vitamins, enzymes, and other bioactive substances.

The unique property of the microbes in NatureVel - WW is that they all work together to devour the very toxic compounds caused by human pollution, which throw ecosystems into a state of rapid decline. This leads to a reduction in the BOD and consequently the COD. As the reduction takes

place without the use of DO (Dissolved Oxygen), the oxygen level of water is quickly increased with reduced need for aeration, thereby leading to cost reduction.

Also, these microbes create an organic polymer around the suspended particles, thereby increasing settle ability, leading to increased efficiency in cleaning wastewater.

Furthermore, as the NatureVel-WW dosed effluent makes its way through the sewage system, it has the effect of purifying the liquid sewage it mixes with as well as the sewers as it passes through. It then goes on to play a similar role in helping to clean up pollution in rivers when it empties into them.

NatureVel – WW microbes remove foul odor from any kind of water contamination at a very fast pace. This is done through five separate ways. These are:

1. Odor substances are of weak alkaline nature and are primarily represented by ammonia. It is neutralized with organic acids in Naturevel-WW solution.
2. The enzyme and antioxidants reduce odor in a synergistic way, a sort of buffer effect.
3. The metallic chelates react with odor substances instantly, change them into non-odor substances and reduce them quickly.
4. Foul odor is emitted by putrefactive type of microorganisms. When NatureVel - WW is applied to a local environment and starts to dominate it with its fermentation type of microorganisms, they will stop the process of putrefaction and move towards a fermentation process.
5. The herbal extracts in NatureVel – WW help to further clean the wastewater and also suppress foul odour.

e. **NatureVel – WW improves the Environment and not harm it in any way:** Our product, NatureVel – WW does not harm the environment in any way. On the contrary it improves it. Evidence of the same are as follows:

- The product is being made in India and not being imported from any Country.
- All microbes in NatureVel – WW are non-GM (not Genetically Modified). Evidence of the same is the Organic Certificate given to us by APEDA through their accredited certification agency ECOCERT. We are printing the type of microbes on our label, thus making it extremely transparent.
- There are various case studies to support that individual microbes in NatureVel – WW are harmless.

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Bio-Graphical Details of the Author:

Mr. Sanjay Aggarwal is a Commerce graduate and completed his MBA from XLRI. Though being a Management Graduate, he was always fascinated by nature and the millions of solutions it could possibly bring for humanity. After working with many Companies, he became the CEO of a small Biotech Company, which was manufacturing biotech products in collaboration with a Company in Japan. Thereafter, he started his own Company – Clover Organic Pvt. Ltd., in collaboration with Biosa, Denmark. Though the collaboration provided powerful beneficial microbes, he thought of providing end-to-end solutions to mitigate pollution, while creating prosperity in the fields of agriculture and allied lines on one side and waste management on the other end. His 15 years of experience in working with the best in the business, has given him the experience to lead his team to create ecological and innovative solutions to complex problems.