निसर्गऋण प्रौद्योगिकी

1

निसर्गऋण : पर्यावरण संतुलन की दिशा में 25 वर्षों की यात्रा

सयाजी मेहेत्रे[1,2*]

[1]नाभिकीय कृषि एवं जैव प्रौद्योगिकी प्रभाग, भाभा परमाणु अनुसंधान केंद्र, ट्रांबे, मुंबई-400085, भारत
[2]होमी भाभा राष्ट्रीय संस्थान, अणुशक्ति नगर, मुंबई-400094, भारत

निसर्गऋण-जेएनपीटी

सारांश

भाभा परमाणु अनुसंधान केंद्र, मुंबई ने रसोईघरों, बाज़ारों और बूचड़खानों में उत्पन्न होने वाली जैव अपघटनीय अपशिष्ट संसाधन पदार्थों के प्रसंस्करण के लिए निसर्गऋण प्रौद्योगिकी विकसित की है। यह प्रौद्योगिकी जीवन को बनाए रखने में प्रकृति और धरती मां की भूमिका को स्वीकार करती है और हमें संसाधनों के पर्याप्त रूप से सदुपयोग में अपनी भूमिका निभाने की याद दिलाती है ताकि आने वाली पीढ़ियां भी जीवन की समान गुणवत्ता का आनंद ले सकें। यह एक जैव-मेथैनन प्रक्रिया है जिसमें वायवीय एवं अवायवीय चरण शामिल हैं जो जैव-अपशिष्ट के पूर्ण क्षरण को सुनिश्चित करता है। इससे आयतन में लगभग 90% की कमी होती है। इसके दो उपयोगी उप-उत्पाद हैं- समृद्ध मीथेन के साथ बायोगैस और एक उत्कृष्ट मृदा अनुकूलन के रूप में उच्च गुणवत्ता वाली जैविक खाद। इस प्रौद्योगिकी विकास की यात्रा वर्ष 2001 के दौरान शुरू हुई जब भापअ केंद्र परिसर के भीतर स्थित नर्सरी में पहला प्रायोगिक संयंत्र स्थापित किया गया । इस लेख में निसर्गऋण कार्यान्वयन की वैज्ञानिक एवं तकनीकी यात्रा का अवलोकन शामिल किया गया है।

NISARGRUNA Technology

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NISARGRUNA: 25 Years Journey Towards Sustainable Environment

Sayaji Mehetre[1,2*]

[1]Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Trombay-400085, INDIA
[2]Homi Bhabha National Institute, Anushakti Nagar, Mumbai-400094, INDIA

Nisargruna-JNPT

ABSTRACT

Bhabha Atomic Research Centre, Mumbai has developed NISARGRUNA technology for processing of biodegradable waste resource materials originating in kitchens, markets and abattoirs. The technology acknowledges the role of Nature and Mother Earth in sustaining life and reminds us to play our role in resource handling adequately so that future generations also can enjoy the same quality of life. This is a bio-methanation process involving aerobic and anaerobic phases which ensures complete degradation of bio-waste. The volume reduction is about 90%. There are two useful byproducts viz. biogas with enriched methane and high-quality organic manure as an excellent soil conditioner.
The journey of the technology development has started during 2001 when first pilot plant was installed at Nursery, inside BARC campus. Overview of the scientific and technological journey of Nisargruna implementation has been covered throughout this article.

KEYWORDS: *Nisargruna, Biogas, Bio-waste*

*Author for Correspondence: Sayaji Mehetre
E-mail: smehetre@barc.gov.in

Introduction

A basic tenet that governs the sustainability of our planet is conservation of matter and energy. Continuation of Nature's biogeochemical cycles of various elements is central to this sustainability. The concept of *NISARGRUNA* (which means Nature's loan) is to understand the laws of Nature and, accordingly, play our part as responsible inhabitants of this ecosystem. There is no word called waste in the dictionary of Nature. Viewed in this perspective, waste is not something to be dumped in total disregard to the ecosystem. Wealth contained in waste, in the form of matter and energy, must be recycled and reused.

Unfortunately, waste is associated with a number of negative qualities. Apart from the stink and unsightliness, generation of waste is invariably decentralized. Modern urban societies centralize the collection of waste and, in the process, create problems of mammoth size. Large areas, difficult to find in urban settings, are required to dump our wastes. Dump yards spread stink and ill health and leach toxic substances into ground water. Biodegradable waste materials can reduce the value of dry recyclable waste, when both are mixed. If the biodegradable wastes can be processed separately, subsequent value addition in the remaining waste, mostly recyclable, can lead to economically viable waste management.

Organic matter content of soil is an important component of sustainable agriculture. Though Indian soils have been productive over thousands of years, organic matter in our soils has considerably declined over a period of time. Application of organic manure is a time-tested method to replenish the organic content of soil. Biodegradable wastes generated in kitchens and vegetable markets and agro-wastes generated in agricultural fields are important sources of organic manure. However, these wastes need to be processed before they can be applied as manure. NISARGRUNA technology offers a comprehensive solution to handling biodegradable wastes and is based on the concept of maintaining the elemental balance in nature.

NISARGRUNA plant is designed around the basic concept of safe and environment-friendly treatment of biodegradable wastes, combined with generation of energy in the form of biogas. It offers a decentralized alternative for processing the biodegradable waste generated in human settlements. Basically, it is a biphasic biomethanation plant that can generate about 60-100m^3 of biogas (about 20-30kg of methane) per tonne of waste processed. The gas can be used either for cooking or for electricity generation. Manure, obtained after waste processing, is rich in nitrogen and can be used as an excellent soil conditioner. The carbon to nitrogen ratio of this manure is similar to that of fertile land (12:1). It has good quantities of phosphorous, potassium, iron and magnesium. Moreover, it is weed-free and does not have any offensive smell[1,2].

Principle of Nisargruna Technology

The organically rich bio-degradable portion of solid waste is mixed with water to form slurry. The slurry is then aerobically digested in the predigester, wherein organic matter is converted to organic acids. The predigestion is accelerated by addition of hot water and intermittent aeration. Predigestion reactions are exothermic and the temperature rises to 40^{o}C by itself. Hot water obtained using solar energy is added to raise the temperature to 45^{o}C. Their main role is to digest fats, proteins and low molecular weight carbohydrates to produce organic acids and volatile fatty acids.

The smaller molecules like proteins and simple carbohydrates are degraded during predigestion. The pH of the feed slurry to predigester is around 7.0 - 8.0. The retention time (*Hydraulic time*) in the predigester is 4-5 days. After the predigestion the pH reduces to 4-5. The predigested slurry is further digested under anaerobic conditions for about 25 days. The process of methanogenesis takes place in this digester. Methane and carbon dioxide are the terminal products of this process. Methane is produced from two primary substrates viz. acetate and hydrogen/ carbon dioxide (formate). At this stage the organic acids are converted by consortium of methanogenic bacteria to methane and carbon dioxide.

The undigested lignocelluloses and hemicelluloses then flow out as high quality organic manure slurry. The pH of this slurry ranges from 7.5-8.0.

The three steps of biogas production are as follows: 1) hydrolysis 2) acidification and 3) methanogenesis. Various bacteria are involved in these processes.

Hydrolysis

In this step, the organic matter is hydrolyzed by extra-cellular enzymes (cellulase, amylase, protease and lipase) of microorganisms in the pre-digester tank. Converting solid waste into liquid form in the mixer stimulates this step. Bacteria start decomposing the long chains of the complex carbohydrates, proteins and lipids into shorter parts. Proteins are split into peptides and amino acids. Simple carbohydrates and lipids are degraded completely into organic acids and fatty acids.

Acidification

Acid-producing bacteria involved in the second step convert the intermediates produced in the hydrolysis step into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2) in the predigester. These bacteria, of the genus *Bacillus*, are aerobic and facultative anaerobic, and can grow under acidic conditions. An air compressor maintains aerobic conditions in the predigester. To produce acetic acid, the bacteria use the oxygen dissolved in the solution or bonded oxygen. Hereby, the acid-producing bacteria reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. The pH of the raw slurry falls from 7.5 to about 4.5 to 5.5 in the pre-digester. It appears that in the predigester, various zones are formed and different bacteria dominate these zones.

Addition of hot water helps in eliminating the mesophilic bacteria and selection of thermophilic bacteria. But these thermophilic bacteria can operate at lower temperatures also. Hence hot water added even once a day should be sufficient for maintaining the pure consortium in the predigester. However, if it is possible to maintain the temperature of the predigester in

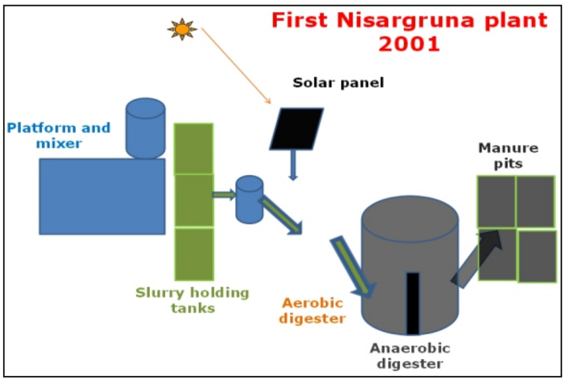

Fig.1: Schematic diagram of the first plant installed at Nursery 2001.

Photo.1: First Nisargruna plant installed at Nursery, BARC 2001.

the range of 50-55°C throughout the day, the performance will definitely be better and the holding time may be further reduced. The hot water helps in hygienization of the slurry by killing the enteric bacteria that may be present in the waste. Some Gram negative enterobacteria and coliform bacteria have been isolated in the raw slurry. However, in the second zone these bacteria are totally eliminated. From the pre-digester tank, the slurry enters the main tank where it undergoes anaerobic degradation by a consortium of methanogenic bacteria belong to the archaebacteria group. These bacteria are naturally present in the alimentary canal of ruminant animals (cattle). They produce methane from the cellulosic materials in the slurry. The undigested lignocellulosic and hemicellulosic materials are then passed on to the settling tank. After about a month, high quality manure can be dug out from the settling tanks. There is no odour in the manure and the organic content is high, which can improve the quality of humus in soil.

Methane Formation

Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. Under natural conditions, methane-producing microorganisms occur wherever anaerobic conditions are provided, for instance under water (in marine sediments), in ruminant stomachs and in marshes. They are anaerobic and very sensitive to environmental changes. In contrast to acidogenic and acetogenic bacteria, methanogenic bacteria belong to the archaebacteria group, a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial genera. It is advisable to circulate the generated biogas back into the system using a small compressor. This would enhance the reduction of carbon dioxide to methane and enrichment of methane fraction in the biogas.

The separation of two stages in methane production helps in improving the purity of methane gas, thereby increasing its fuel efficiency. However, the average composition round the year would depend on how effectively predigester temperatures can be maintained. The gas is finally taken through a GI/plastic pipeline to utility points. Drains for condensed water vapor are provided online. The biogas burns with a blue flame and is ideal for cooking. Alternately, it can be used to produce electricity in a dual fuel biogas-diesel engine.

Installation of Nisargruna Technology

First Nisargruna plant was installed during June 2001 at Nursey, opposite to CFB inside BARC campus. The design of the plant is shown in Fig. 1 and Photo 1. The capacity of this plant was 0.5 MT/year. It was the crude prototype with a minimum of infrastructure. It was only an idea which was put into action. After seeing the success of this idea, we were encouraged to develop more plants[1].

The technology got improved over the period of time as per the material available for processing. Important functional modifications were added subsequently. Aeration grid was improved the process was fairly under control. Many gadgets were added in the design of the plant. Over the subsequent years more safety applications and gas utilization aspects were added (Fig. 2)[4].

Utilization of the gas has played significant role in the success of the technology. So gas utilization aspects were added during recent times. This includes electricity generation, gas turbine, community kitchen, vehicle applications etc.

Presently the design given in Fig. no 3 is followed by all the technology licensees. The system includes gas utilization, gas storage, manure enrichment and water cycling etc.

Thus the technology has evolved over the period of time and functioning for the effective management of the biodegradable waste.

Use of Manure as a Soil Conditioner

There is always demand for the manure for soil application, the question is where to get the enormous quantities of organic matter? The concept of bioenergy can provide us both energy and valuable manure. Nature has shown us an excellent way of harvesting solar energy through biological route. Every living cell is an energy power house. Directly or indirectly it uses solar energy. Every bio-molecule is loaded with energy. This route of harvesting energy through NISARGRUNA concept also ensures that we get an energy rich soil conditioner. This will help in replenishing the depleting top soil layer providing us sustainable and dynamic soil matrix to fulfill our food demand. The route also ensures the

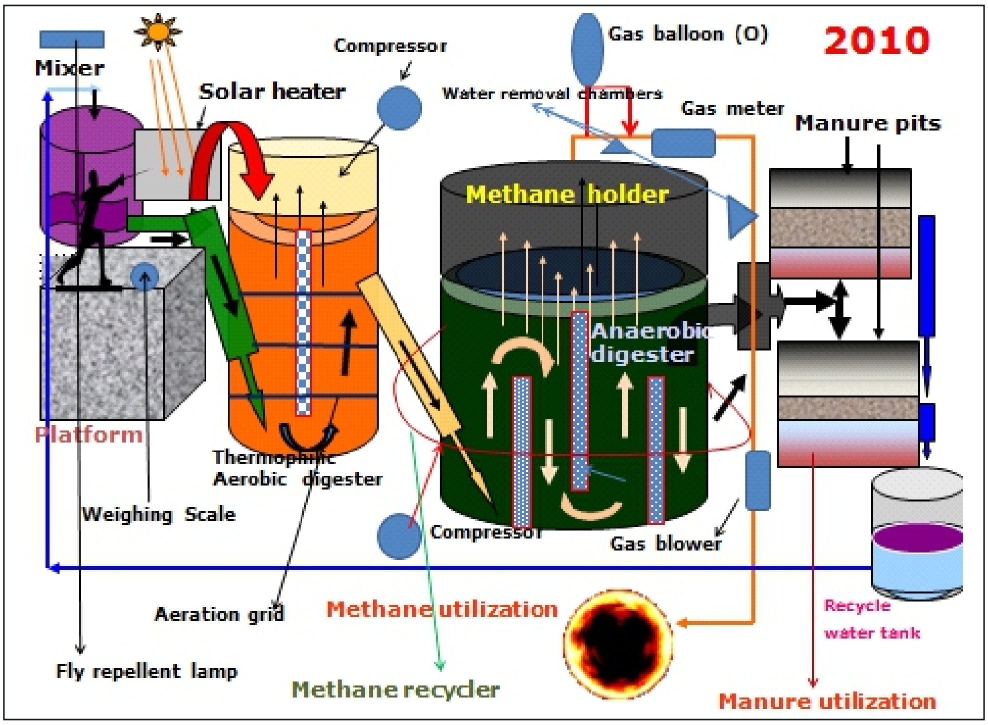

Fig.2: Schematic diagram of the plant.

continuation of biogeochemical cycles of various elements. Indian farmland extends to about 142 million hectares. Each hectare needs about 2-3 MT of good quality organic manure per year. This will also help to reduce substantially the use of chemical fertilizers.

Biogas use, replacing conventional fuels like kerosene or firewood, allows for the conservation of environment. It therefore, increases its own value by the value of saved traditional fuels i.e. forest saved or planted. The price of supplied energy produced by biogas competes with distorted prices on the national or regional level of the energy market. Monopolistic practices, which enable energy suppliers to sell their energy at a price higher than the competition price, still dominate the energy market in many countries including India. A decentralized, economically self-sufficient Nisargruna unit therefore - under competitive conditions - provides its energy without market distortions[3].

Reduction of the Greenhouse Effect

NISARGRUNA technology plays an important role in global struggle against the greenhouse effect. It reduces the release of CO_2 from the burning of fossil fuels in two ways. First, biogas is a direct substitute for liquid petroleum gas (LPG), kerosene or coal for cooking, heating, electricity generation and lighting. Additionally, the reduction in the consumption of artificial fertilizer avoids carbon dioxide emissions that would otherwise come from the fertilizer producing industries. By helping to counter deforestation and degradation caused by overusing ecosystems as sources of firewood and by melioration of soil conditions NISARGRUNA technology reduces CO_2 releases from these processes and sustains the capability of forests and woodlands to act as a carbon sink.

Methane, the main component of biogas is itself a greenhouse gas with a much higher “greenhouse potential” than CO_2. Converting methane to carbon dioxide through combustion is another contribution of Nisargruna technology to the mitigation of global warming. This holds true as the material used for biogas generation would otherwise undergo anaerobic decomposition releasing methane to the atmosphere. Of course, burning biogas also releases CO_2. But this, similar to the sustainable use of firewood, does only return carbon dioxide which has been assimilated from the atmosphere by growing plants few year(s) before. There is no net intake of carbon dioxide in the atmosphere from biogas burning as is the case when fossil fuels are burnt[5,6,7].

Advantage of the Technology

- Environmental friendly processing of biodegradable waste is achieved. This waste is completely zeroed and by-products are generated.
- The elemental cycles like nitrogen, carbon, hydrogen, oxygen etc. cycles expect that the biodegradable waste has to go through microbial route for ensuring their availability for future life. Nisargruna achieves this objective fully.
- The processing cost of biodegradable waste is far lesser compared to any other foreign technology.
- Decentralized handling of the waste will reduce the transportation costs, dumping yard needs and assured processing. In long run, it means that dumping yards could be totally eliminated. If proper segregation occurs at the source, then the requirement of land-fill sites can be reduced by 60-70%.

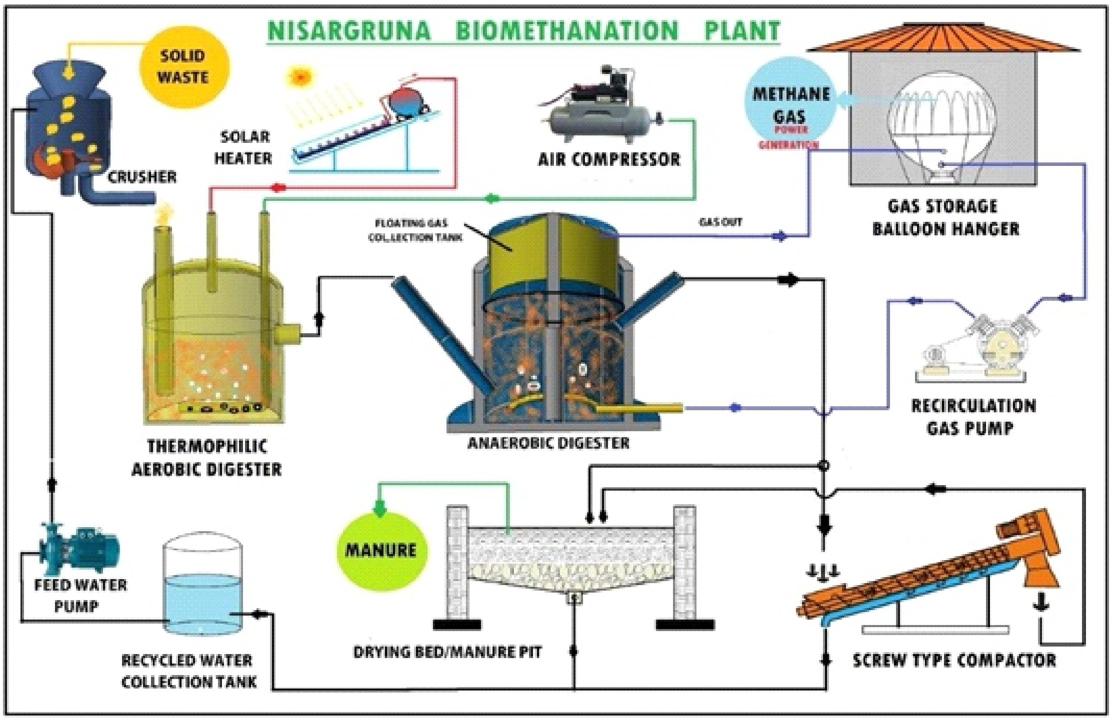

Fig.3: Current design of the Nisargruna technology.

- Transportation of this waste through crowded areas could easily be avoided if decentralized Nisargruna plants are made available.
- By-products like biogas and manure can make the process economically attractive.
- Processing of solid biodegradable waste in this manner would ensure that this material won't be carried to dumping yards and release methane there, in slow and unplanned composting. Since the biogas is trapped to burn, the contamination of environment with a vast quantity of methane will be completely avoided. This would earn carbon credit.
- The use of biogas as fuel will save the classical fuel consumption including petrol, LPG and diesel. This is another reason which will ensure the carbon credit for the process.
- In rural areas where biomass can be made available to run these plants, energy-freedom can easily be achieved. The stand-alone Nisargruna plants can be rural power houses.
- It offers a long-life methodology to treat the biodegradable waste in a very limited space. The continuity of the process makes it possible to treat a large quantity of waste at a single site without any need of adjoining areas.
- The technology is relatively simple and does not involve any imports. The plants can be operated by unskilled workers after training them initially for about 3-4 weeks. It is developed keeping in mind local environment and the types of wastes.
- The manure generated in the process will help in rejuvenating the depleting organic carbon contents in our agricultural soils.

Technological Improvement/Upgradation: Generation of *'Shesha'*:

A novel, compact helical shaped digester cum waste converter made of low-cost PVC pipes has been developed and deployed for kitchen waste processing during 2021. The name Shesha (शेष) has been given on the basis of the serpentine shape of this digester (its resemblance to the snake Shesha) as well as Sanskrit name of waste (Fig. 4). The system has been patented with Indian Patent No. 531960[4].

The main advantage of this waste converter includes helical shaped digester made from low-cost PVC pipes which saves major cost of construction and MS dome required for conventional designs. It is suitable for skid mounting on a vehicle or wheels required for processing waste from smaller societies/residential complexes. Also, the design has inbuilt suitability of biogas recycling for methane enrichment and suitable for online monitoring of process parameters. The overall process includes converting organically rich bio-degradable portion of solid waste to slurry by mixing equivalent quantity of water and it is almost the same as occurred in Nisargruna except the plug-flow system. The undigested lignocelluloses and hemicelluloses then flow out as high-quality organic manure slurry. It has been observed that waste is converted into good quality manure and the gas generation is substantial.

The overall process includes converting organically rich bio-degradable portion of solid waste to slurry by mixing equivalent quantity of water. The slurry is then aerobically digested in the predigester, where organic matter is converted to organic acids. The predigestion is accelerated by addition of

Fig.4: Shesha pilot plant installed at Training School Hostel during 2021.

hot water and intermittent aeration. Hot water obtained using heating the gas itself. The smaller molecules like proteins and simple carbohydrates are degraded during predigestion. The pH of the feed slurry to predigester was around 7-8. The retention time (Hydraulic time) in the predigester was 3-4 days. After the predigestion the pH reduced to 4-5. The predigested slurry was further digested under anaerobic conditions for about 25 days. The process of methanogenesis takes place in the digester made up of PVC pipes. At this stage the organic acids are converted by consortium of methanogenic bacteria to methane and carbon dioxide. The undigested lignocelluloses and hemicelluloses then flow out as high-quality organic manure slurry. The pH of this slurry ranges from 7.5-8. It has been observed that waste was converted into good quality manure and the gas generation was substantial. All the microbial and biochemical parameter of the waste was achieved at the end of the process.

Conclusion

Nisargruna technology has matured over the period of time and also proved successful across different sectors of the society. But still there are hurdles in wider application of the technology. These includes

1. Mostly the problem comes when the waste is not segregated properly. The non-degradable material like plastic, iron nails, etc brakes mixer resulting in not functioning plant properly.

2. There are no operational difficulties as far as technology is concerned. Two pilot plants installed at Nursery inside BARC and TSH, Anushaktinagar are working without any major difficulty for last 25 years. During lockdown also plants were working efficiently.

3. Waste management is responsibility of government agencies like municipal corporation, municipal councils, state government so there is delay in implementation of project. Coordination between different agencies is required.

4. Installation and maintenance costs are increasing with time. So government should give some support for its sustainable implementation.

The technology has showed path towards sustainable management of waste and it is our duty to follow all the processes in scientific way for sustained working of the plant.

Acknowledgement

The authors express gratitude to Dr. S. K. Ghosh, former Associate Director of Bio-Science Group, BARC and Dr. S. P. Kale, Ex Associate Director, Bioscience Group & Head, NA&BTD for his invaluable support and continuous guidance since inception of the project followed by execution.

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