CONNECT

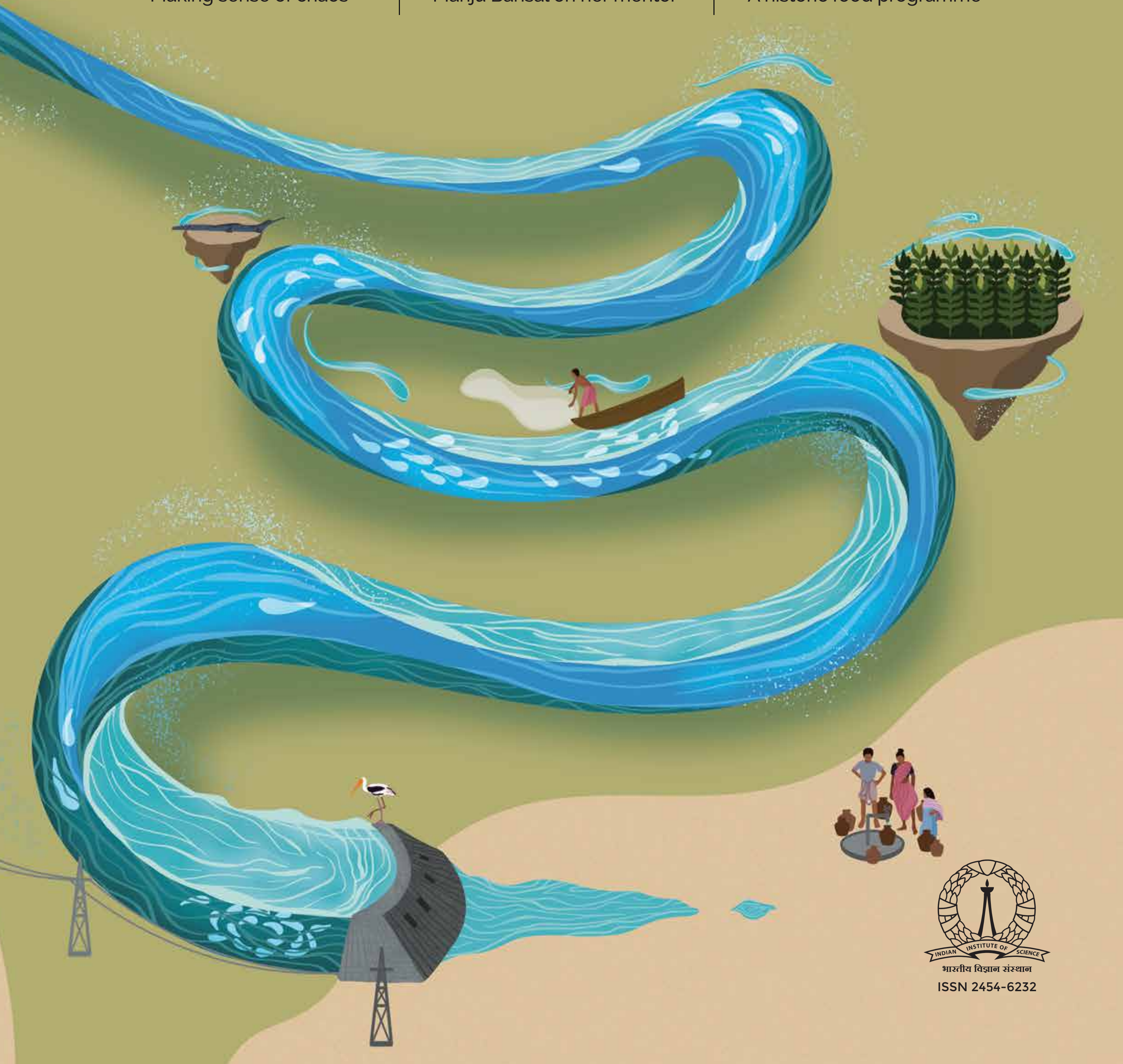
WITH THE INDIAN INSTITUTE OF SCIENCE

Volume 9 Issue 3 September 2022

Assam floods
Making sense of chaos

Remembering GNR
Manju Bansal on her mentor

Soya milk
A historic food programme



भारतीय विज्ञान संस्थान

ISSN 2454-6232

IN THIS ISSUE

Editorial

Water gives life, but it can also wash away livelihoods. In this issue of *CONNECT*, we take a closer look at the diverse impact of water on our lives. Science and society come together in the story of Assam's increasingly destructive floods. Studies of polluted rivers paint a grim picture, and the quest for providing clean drinking water continues, as does the search for new techniques to reuse wastewater. A simple molecule, water also works in complex ways to enable vital processes within our bodies.

Did you ever wonder how much water we consume on campus? Radhika Muthukumar, an Assistant Project Engineer whom we shadowed for a day, has the answer.

In other stories, Manju Bansal pens a tribute to her mentor, GN Ramachandran, on the occasion of his birth centenary. Mythra Gangadharaiah looks back on her 34 years at IISc, most of them spent at the Institute library. Office staff talk about what motivates them to add that extra green touch to their surroundings. Read about a large-scale programme that provided soya milk to thousands of schoolchildren in the 1940s, and about the complicated decisions involved in digitising archival material. And finally, the Chair and office manager of IPTeL tell us about intellectual property rights and get into the nitty-gritty of filing patents.

Happy reading!

Team Connect

Bitasta Das, Deepika S, Narmada Khare, Pratibha Gopalakrishna, Ranjini Raghunath, Samira Agnihotri (Coordinator), Vibhu Vasudev

Contact

Email: connect.ooc@iisc.ac.in

Phone: 91-80-2293 2066

Address: Office of Communications,
Indian Institute of Science,
Bangalore 560 012

Website: http://connect.iisc.ac.in

Design: Magnetyz

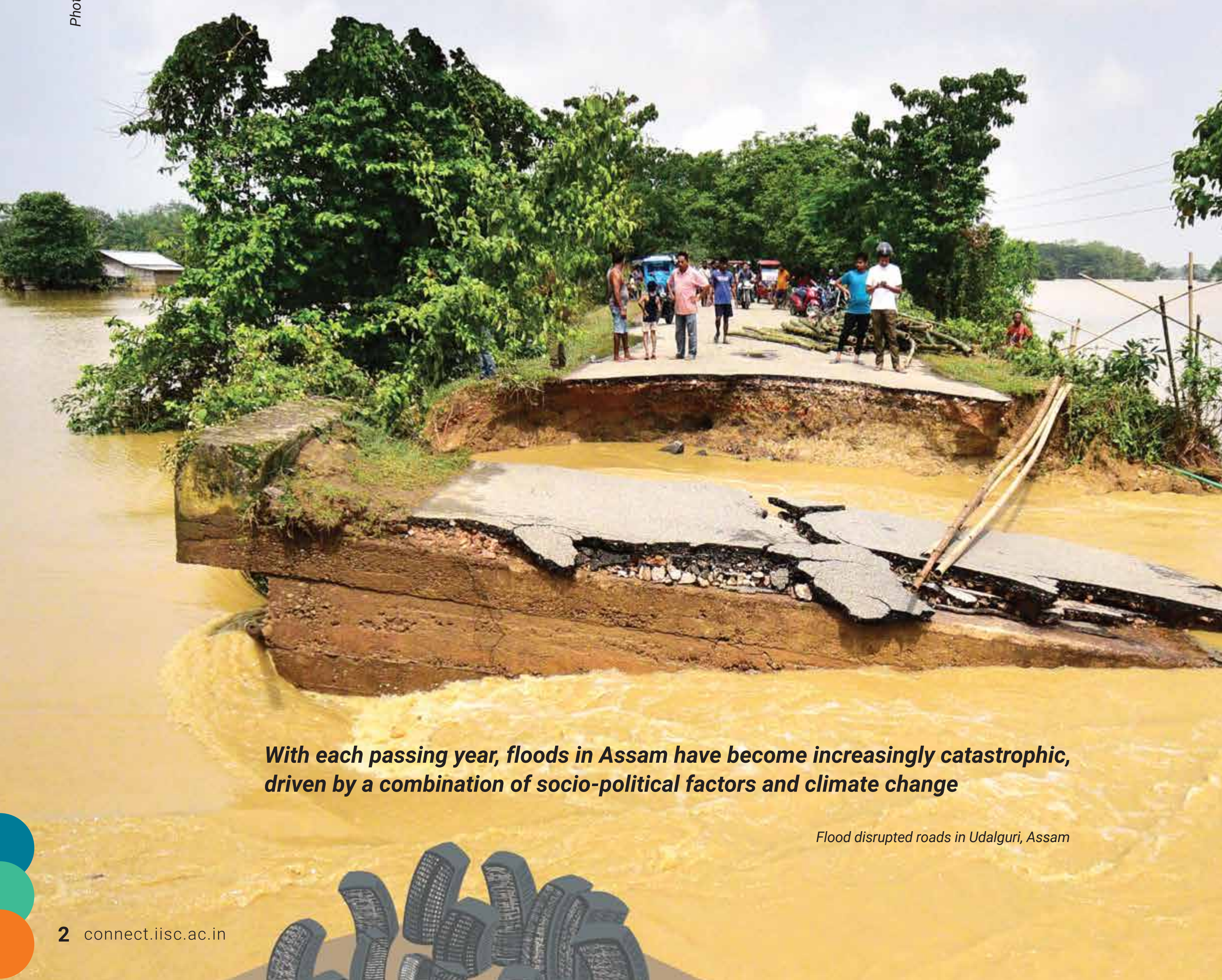
Cover illustration: Swadha Pardesi

Printer: Sri Sudhindra Offset Process

From Boon to Bane: THE CHANGING FACE OF ASSAM'S FLOODS

- Bitasta Das

Photo courtesy: Kumud Das, DY365



With each passing year, floods in Assam have become increasingly catastrophic, driven by a combination of socio-political factors and climate change

Flood disrupted roads in Udalguri, Assam

The Udalguri district in Assam, which shares an international border with Bhutan, has historically been a peaceful area. But in recent times, this district, like many others across the state, has been pummelled by floods year after year. When I was travelling from Guwahati to Tezpur in June this year, we had to stop in Udalguri to change our route because the floods had broken up the connecting roads between many parts within the state. At least 10 villages in this district were fully submerged. The situation is bleaker because the district is also reeling from the impact of COVID-19. The common lament I heard from some of the people living there was how they have been scared to step out of their homes due to COVID-19, but the floods have now left many of them homeless, placing them in a desperate situation.

A state like Assam, with its large network of rivers, has always been prone to floods. It lies along one of India's top four flood-prone regions: the Brahmaputra basin, into which more than 50 tributaries feed. While the rest of the country also witnesses different types of floods such as coastal, urban, river and ponding floods, as well as occasional flash floods, Assam has been particularly suffering from more frequent and far more devastating floods. The lowlands and riverine areas in Assam are among the most affected, leading to the destruction of valuable farmland.

Jessica Bodosa, a former UG student at IISc, says that this year too, like in the previous years, the flood has completely destroyed her relatives' paddy crop in the Rangia district of Assam.

Rohit Borooah, a former MSc (Engineering) student at the Centre for Sustainable Technologies, IISc, and a native of Guwahati, says that it is the loss of lives every year that disturbs him the most. "Not just human lives, but also animal lives," he adds. "About 95% of Kaziranga National Park becomes submerged in water during the monsoons. Over the past few years, the intensity of the floods has increased and even the higher ground areas where animals would earlier find refuge are now flooded. Wild animals find no place to retreat within the forest and they often wander on the highways, which in turn leads to conflict with the human population of the vicinity."

Jinna Bordoloi, a former Research Assistant at the National Institute of Advanced Studies, Bangalore, adds that Nagaon, the town where her sister lives, has been inundated by floods not just once but twice this year, for the first time in 50 years.

This year's floods are believed to be the worst in 122 years. 200 people have died, and several wild animals in sanctuaries have lost their lives. Road and train tracks have been disrupted and thousands have been displaced. Every year, the loss of lives, property, infrastructure and public utilities grows greater. But this devastation is only a symptom of a larger problem.

Photo courtesy: Kumud Das, DY365

Damaged houses in Rangia, Assam

From bounty to devastation

The history of Assam's floods is crisscrossed with social, political and environmental developments.

Jagdish Krishnaswamy, Dean, School of Environment and Sustainability at the Indian Institute of Human Settlements, Bangalore, has studied river hydrology and ecology for many years. According to him, the story of Assam floods should begin with an appreciation of its role in the state's ecological assets and ecosystem services. He says, "Floods generate a bounty of fish and rejuvenate flood-plain ecosystems all along the Brahmaputra, including in the Kaziranga. This landscape has been shaped over millions of years with the help of an active monsoonal environment and mighty rivers that carry sediments weathered from the Himalaya."

Over millions of years, this depositing of sediment into the floodplains has produced two significant results: raising the lowlands and regularly adjusting river beds. These crucial processes ensured that the impacts of flooding remained moderate. However, the low intensity of impact on the floodplains emboldened humans to encroach into nature, he says. Things began to change rapidly in the 20th century. As the human footprint accelerated on the floodplains, the landscape became increasingly "developed and engineered." This engineered landscape has affected the floodplains mainly in two ways: it has undermined their ability to store and absorb water, and reduced their capacity to transport sediment. These historical developments, together with climatic factors, have made the region vulnerable to severe flooding.

PP Mujumdar, Chair of the Interdisciplinary Centre for Water Research, IISc, specialises in the study of climate change impacts on hydrology and water resources, and works extensively on understanding the increasing magnitude and frequency of floods under climate change at urban and riverine scales. According to him, the risk of and vulnerability due to floods have increased tremendously around the world. In most regions, this is because of high intensity precipitation. But there are also individual events specific to particular regions. For example, the Uttarakhand flood in 2021, which was initially thought to be Glacial Lake Outburst Flood (GLOF), had many other triggers, such as an avalanche caused by a hanging glacier that had separated from a mountain and plummeted into the Ronti, a tributary of the Rishiganga river. Similarly, the Kerala flood of 2018 was aggravated due to high ocean tides. Despite decades of research, there are still uncertainties in pinpointing the exact cause of floods. Recent floods are generally attributed to climate change by the public. However, science has not yet advanced to the stage where one can attribute a single extreme event like a flood specifically to climate change, Mujumdar adds.

HN Chanakya, a former Chief Research Scientist at the Centre for Sustainable Technologies, IISc, has been associated with Assam for the last five decades. Some part of his childhood was spent in the city of Jorhat. In recent years, he has visited Assam many times for his research. He has observed several changes during this time that he feels have contributed to the devastation in the state. For one, the population of the once sparsely populated state has rapidly increased. Earlier the lowlands used to be unoccupied, now there are human settlements. Secondly, land that was traditionally used for agriculture is now being used for constructing buildings. The third and the most worrying change he mentions is that flood preparedness, which was once part of the people's lifestyle, is now missing. People have known for centuries that the Brahmaputra and Barak rivers increase in volume during the monsoon. Every household in low-lying areas used to be prepared with a banana raft or a boat for sailing to higher shores if needed. Chanakya believes that this readiness is missing now.

Jinna also feels that human behaviour is contributing to flood-related disasters. "When I returned to India in 2019 after studying at Cornell University, I could not see many ponds and paddy fields [that I once used to see in my childhood]. Instead there were buildings without proper drainage systems. In our childhood, celebrations of Durga Puja were few and far between, but now every lane organises one puja pandal. Thousands of idols are dumped in the Kalong river after the celebration. I feel like the river has lost the capacity to hold water." Her father served as a government engineer in Assam. From what she's gleaned and heard from conversations, she says, floods have opened up new avenues for corruption by handing over contracts for rescue operations to unscrupulous agencies in exchange for bribes.

Banking on embankments

After India's independence, the erection of river embankments was touted as the best solution for preventing floods. The existing embankments on the main stem of the Brahmaputra and its tributaries were built in the 1960s and 1970s. Experts have pointed out how such embankments need to be improved to reduce the impact of floods. The Government of India's Standing Committee on Water Resources (SCWR), in its 12th report published on 5 August 2021 stated, "These embankments need raising and strengthening as well as bank protection measures in the form of revetment or Reinforced Cement Concrete (RCC) requiring huge capital investment."

Photo courtesy: PP Mujumdar and his lab

Field study to find sustainable solution to water logging

Apart from the limitations of using embankments, news reports suggest that the devastation in the floodplains in some parts of India including Assam is also a consequence of the way the dams and reservoirs are operated – suddenly releasing large quantities of water from a dam can quickly submerge low-lying areas. Work by Jagdish and his colleagues has shown that such human interventions to "tame" rivers and "stabilise" hydrologically dynamic landscapes and riverscapes should be avoided if possible, or done according to the guidelines that account for the environmental conditions in northeast India, incorporating the fragile geology, changing rainfall patterns, high seismicity and the risk of landslides. Jagdish adds that we also need early-warning systems as well as livelihood and development pathways that can adapt to the dynamics of flood-plains.

D Nagesh Kumar, Professor at the Department of Civil Engineering, IISc, points out that ageing infrastructure is also a significant deterrent in flood control. Many dams that have been protecting cities from the onslaught of floods are now very old. They might soon be unable to accommodate the extra water added due to floods.

Some portion of the storage in the dams is already lost in holding sediments. This will, in turn, create a consequential problem. For example, when the Almatti dam on the Krishna River gets filled, the surplus water flows to the Bhadra and Tungabhadra dams. But the Bhadra dam has already lost almost half of its storage capacity due to sedimentation. Within no time, it can get filled, flooding nearby areas like the Lakkavalli village and Bhadra Wildlife Sanctuary, and eventually leading to a huge amount of water getting dumped in the ocean.

Both Nagesh and Chanakya admit that the floods in Assam are unique due to its geographical location. Besides these internal missteps, there is also the fact that the Brahmaputra is an international river. There is not enough data on water management that is shared across the border. There are also reports that China is constructing a dam on the river in the east, and there could be a cascading disaster if the water in this dam is released in an uncontrolled manner, adding to Assam's woes.

The silver lining

For a country like India where many districts also suffer from a severe shortage of water, such floods can also offer hope. Nagesh points out that flood water can be stored and utilised judiciously for various needs such as drinking, hydropower generation, and irrigation, as well as water quality maintenance through dilution of the harmful components in water released from drainage activities. Discussions on Integrated Flood Management are gaining steam. The Government of India has also introduced a Dam Rehabilitation and Improvement Project (DRIP) to rejuvenate dams in order to avoid wasting flood water. It has also proposed the interlinking of rivers to curb the wastage of flood water and meet the requirements of water-scarce regions. Nagesh affirms, "At some stage, what is now considered as highly uneconomical will become economical because water's value will substantially increase." However, the ecological consequences of such an endeavour are not yet fully understood. For example, the overflowing flood water maintains the salinity of the ocean water; if this is stopped, then the salt concentration will increase. How would this affect marine life? The monsoon cycle might also change, he explains.

Scientists like Mujumdar and others are also making strides in predicting the occurrence of floods, using computational models. For example, they are trying to pinpoint what would be the "return period" – how many years it will take for a flood of a specific intensity to recur – using historical data for pointers. Scientists have been able to accurately predict the onset of cyclones but forecasting high intensity rainfall is still difficult because the depression fronts move rapidly and are spatially spread out. In many recent cases, it is not the annual maximum that is driving floods, but very high rainfall close to the annual maximum and consistently happening on consecutive days that is causing them, Mujumdar explains. "We are now looking at this pattern and in our analysis, we have shown that these events of very high rainfall on successive days are increasing. This is what is causing loss and havoc."


Photo courtesy: PP Mujumdar and his lab

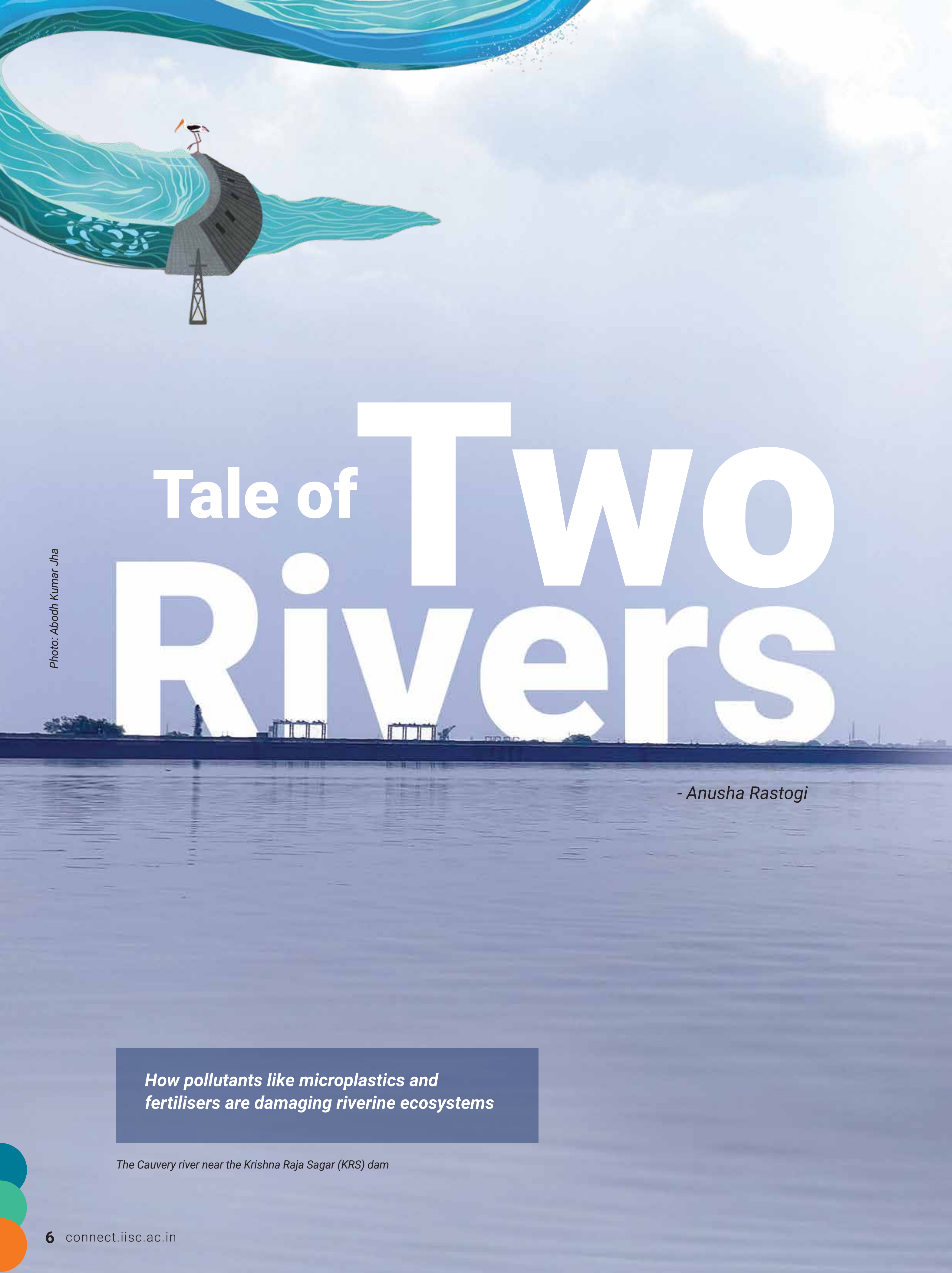
Bangalore city map superimposed with building shapes, used for flood studies

The difference between a pluvial flood, such as in cities like Bangalore and Hyderabad, and a fluvial flood, such as in the river basins of Ganga and Brahmaputra, is the time interval, Mujumdar explains. Urban places become inundated much faster, whereas it takes days to flood river basins. Mujumdar adds that fluvial flood can be better managed with increased technological interventions, and humans and livestock can be evacuated with the help of forecasting tools.

Researchers are also working on trying to prevent the occurrence of floods, even if there is high precipitation. In urban areas, "low impact development measures" are being looked at, explains Mujumdar. These measures include setting up "water corners" like lawns, parks and so on wherever there is space; incorporating perforated pavements for ground water recharge, rainwater harvesting, and developing the idea of "flood as a resource". Mujumdar and his team, in collaboration with the Karnataka State Natural Disaster Monitoring Centre, have developed an app called "Bengaluru Megha Sandesha" that gives information and alerts on rainfall, flood, lightning and thunderstorms in the city.

Apart from such large-scale scientific efforts, there have also been a handful of individual endeavours. Rohit, the former IISc MSc (Engineering) student, had designed and tested a low cost raft made of PVC pipes to aid flood rescue operations a few years ago. But such efforts require support from the government and the public to become widely useful.

A change in people's attitude might also be needed. People in Assam have now started accepting the calamity as an inevitable part of their lives and have become complacent. Jessica says, "No preventive actions are taken, rather the focus is on rescue and rehabilitation after the damage."



Tale of Two Rivers

Photo: Abodh Kumar Jha

- Anusha Rastogi

How pollutants like microplastics and fertilisers are damaging riverine ecosystems

The Cauvery river near the Krishna Raja Sagar (KRS) dam

It's 2022, which means that if the word "river" crops up in a conversation among college students, it would most likely be in the context of a Buzzfeed quiz that seeks to categorise them into a type of river. With the vast number of rivers in India, such a quiz would probably offer a captivating, if misguided, thrill of self-discovery. However, unlike these algorithm-derived virtual results, something about rivers that is fast setting in stone (apart from literal riverbeds), is the decay in their quality due to rampant exploitation in order to meet the needs of our civilisation.

As rivers around the world spill over with contaminants and garbage, and their flow patterns shift due to human-induced climate change, they can spawn diseases in not only the creatures they carry but also in humans who live off of them. Two groups at IISc have been studying the effect of specific contaminants – microplastics and fertilisers – in two major rivers in peninsular India. Research around fertilisers established that human activities such as agriculture were slowly but surely changing the kind of ions present in rivers, altering the chemistry of their basins. In a related vein, a study revolving around microplastics explores the developmental defects that will only escalate as microplastics contaminating rivers collect in our bodies.

Zombie apocalypse: Zebrafish edition

Upendra Nongthomba, Professor and current Chair of the Department of Molecular Reproduction, Development and Genetics, has shared a long history with the Cauvery river. As someone who has spent more than nine years studying and living in Mysore, Nongthomba feels a deep connection to this river that flows through the area. "I still frequently visit Mysore, at least once in every 4-5 months," he explains enthusiastically. "And I like going to the Cauvery backwaters, and eating fried fish from the area."

It was during one of these visits that serendipity struck. He began noticing some unusual deformities in some of the fish being sold and became curious about what was causing these deformities. Although his lab has been using zebrafish as a model to study the toxic effects of contaminants for some time, it was Anifowoshe Abass Toba, a graduate student who joined his lab in 2019, who decided to spearhead a study on the impact of the Cauvery river on the fish living in it. The long-term goal of this project was to understand the effects of polluted water on human health. The discoveries that Abass made using zebrafish were as remarkable as they were disturbing.

Abass started his work from the ground up. The first step for him was to make arrangements to collect the water from the Cauvery. After getting ethics approval from the Cauvery Neeravari Nigama Limited, he travelled to the river frequently during the pre-monsoon period between 2019 to 2021 for water sample collection. With timely assistance from local fishermen, he could also measure the pH, temperature and concentration of dissolved oxygen immediately after collecting the water.

Photo: Anifowoshe Abass Toba

Skeletal deformed fish collected from KRS dam

While researchers have reported earlier that the concentration of dissolved oxygen in the Cauvery has been affected, Abass and Nongthomba both emphasise the woeful lack of any research that seeks to unveil the presence of contaminating microbes and even more dangerously, microplastics. Microplastics have emerged as a dangerous player in the ever-expanding pollution landscape of the 21st century, as they are present in everything from microwavable containers to beer to table salt. Occupying less than 5 millimetres of space in diameter, microplastics are virtually impossible to remove even after the water has been filtered, and are detrimental to human health as well as other vegetation and animals. Alarming new research has shown that these potent contaminants have already entered our bloodstream, with babies and younger children especially susceptible to the accumulation of microplastics in their internal organs.

Scientists believe that one of the primary ways in which microplastics could influence our metabolism is by triggering the generation of a class of compounds known as Reactive Oxygen Species (ROS). ROS interact with various proteins and molecules in our body to hasten ageing, induce inflammatory reactions and cause damage to our DNA. Through a technique known as Raman spectroscopy, Abass was able to identify a variety of microplastics in the Cauvery water.

To study the consequences of these ROS in zebrafish, Abass treated zebrafish embryos to the river water for 96 hours. "We observed a wide range of skeletal deformities, possibly because the microplastics in the water interfere with zebrafish development," he explains. Among these deformities are the improper curvature of the spine, bent tails, irregular larval characteristics and defects around the cardiac area. To conclusively determine if microplastics were indeed responsible for these effects, Abass also treated another set of zebrafish embryos with filtered Cauvery water, thereby removing all impurities other than microplastics. The embryos and larvae continued to show growth defects, proving that microplastics were capable of wreaking havoc during development and possibly after too. Although Abass and Nongthomba are yet to analyse the effects of microplastics on humans, they and other scientists are reasonably confident that similar dangers await us.

Photo: Abodh Kumar Jha

The research team walking towards the skipper at the KRS dam site of the Cauvery river

The ionic basis of pollution

For Ramananda Chakrabarti, Associate Professor at the Centre for Earth Sciences, river chemistry is a fundamental process, crucial to understanding how water interacts with the Earth. As he puts it, "In rivers, the chemistry is largely dictated by the kind of rocks that the water flows over, causing the rocks to weather. As a result, the constituents of these rocks dissolve in the water, altering its composition. This can then influence both the recent environment and the long-term atmospheric composition." Although this might not sound very significant, it can have far-reaching consequences that only gradually become apparent.

Photo courtesy: Ramananda Chakrabarti

Valens Hishamunda, Shiba Acharya, and Rahul DasGupta (left to right)

A few years ago, Ramananda, along with Shiba Shankar Acharya, a National Postdoctoral Fellow in his lab, turned their attention to the Mahanadi river. They started looking at both the natural and human factors that dominate the chemistry of the water in this river. Shiba explains his motivation: "The Mahanadi river is interesting to study because it is one of the largest rivers in peninsular India, and has a unique riverbed consisting of carbonate rocks upstream of the Hirakud Dam, while the area farther downstream is dominated by silicate rocks."

Additionally, information about the Mahanadi basin's composition is mired in confusion. For instance, several studies have reported that the main chemical signature of the river is dominated by carbonates while others suggest that it consists of both silicates and carbonates. Some studies claim that human-induced activities have significantly altered river chemistry, while others refute it.

Piecing together the source of each ion present in the river is nothing short of chemistry-intensive detective work. "Identifying and measuring the ions and radiogenic strontium isotopes present in the river water allows us to pin down if the ion emerged from fertiliser runoff or from a particular industry," explains Shiba.

The Mahanadi river weaves around three important urban settlements namely Sambalpur, Cuttack and Pradeep. To analyse the effect of various discharges from these areas into the river, the authors measured a pollution index. This pollution index was a ratio of contributions of sulphates, chlorides and nitrates to all the ions in the river water – ions that primarily enter the water due to civilisation-induced activities. Nitrates, in particular, have also been widely recognised as an indicator of discharge of fertiliser into the water, particularly during the monsoon and pre-monsoon season. Interestingly, the researchers found the pollution index to be relatively low when compared to other rivers, possibly because the contaminating ions rapidly migrate through the river, and are ultimately diluted by the water.

Collecting the water is a herculean task largely because it has to be sampled from various locations, further complicated by the need to transport it hundreds of kilometres for analysis. For this study, Shiba and his team collected water at different points along a distance of 500 km, spanning the upstream and downstream stretches of the river. After measuring the pH and other properties, a few drops of acid were added to preserve the dissolved ions in the water, and then the samples were processed in the lab at IISc.

By determining concentrations of dissolved ions and radioactive isotopes of strontium ions using different types of mass spectrometers, the authors studied the impact of various candidate molecules and the way they interact to modulate river ion chemistry. They found that the chief contributors to the concentration of ions were carbonate rocks from the river bed, silicate rocks in the lower basin, fertilisers and rainwater during the monsoon period. The presence of phosphate and nitrate ions in the fertilisers and their association with strontium allows them to be easily detected. Like every other natural resource on the planet, the composition of the ions is also subject to seasonal variation, and fertilisers constitute a much smaller fraction during summers and winters.

"The ionic chemistry of rivers changes over geological timescales but it is not easy to predict those changes without a grasp on current trends and composition," explains Ramananda. These trends are also hard to establish because it is not often easy for scientists to understand how much of the variability arises because of the natural weathering of rocks and what fraction is from human contribution. As a result, it is difficult to predict if the detrimental changes are reversible.

On lives and livelihoods

"When I was [studying] at the University of Mysore, I often used to go swimming in the Cauvery river. Now, the water looks so unappealing, I am afraid to get into it," laments Nongthomba. The local residents face even greater struggles: their livelihoods, especially those of the fishermen, are being severely impacted. Several of the local residents shared with Abass fond memories of spending their leisure time around what used to be a clean river.

The greenery and vegetation that once flanked the Cauvery are also slowly becoming a thing of the past. As more and more river water is being redirected to meet agricultural needs, and as the river banks are being encroached upon by people to meet their livelihoods and fuel economies, the river is quickly becoming a reservoir of plastic waste, food leftovers and other debris dumped by human civilisation. For the fishermen, the fear of unemployment and the question of sustenance – the struggle to sell fish of increasingly poor health – rest uncomfortably against a backdrop of lack of education and understanding. "They are worried about the Cauvery being depleted of quality water and declining in biodiversity, but they don't understand that their practices pollute the river too, and they are unwilling to change their ways," explains Abass.

Ramananda presents another slightly disconcerting perspective. "A lot depends on how we interact with our environment," he cautions. "For instance, if we keep pumping groundwater [out] in coastal regions, the rivers would flow in to fill that space and the sea would move into previously freshwater spaces, increasing the salinity of the rivers." While the presence of some extra salt might not sound too scary in theory, it can completely remodel the flora and fauna of rivers and the land around it in the long run.

The leaking of contaminants such as lead and other heavy metals into freshwater sources presents yet another problem with widespread ramifications. "Once they are taken up by fish and other aquatic animals, their concentration only increases with each stage in the food chain, slowly poisoning the people who consume them," he explains.

Photo: Abodh Kumar Jha

Fishermen who help in fish sample collection

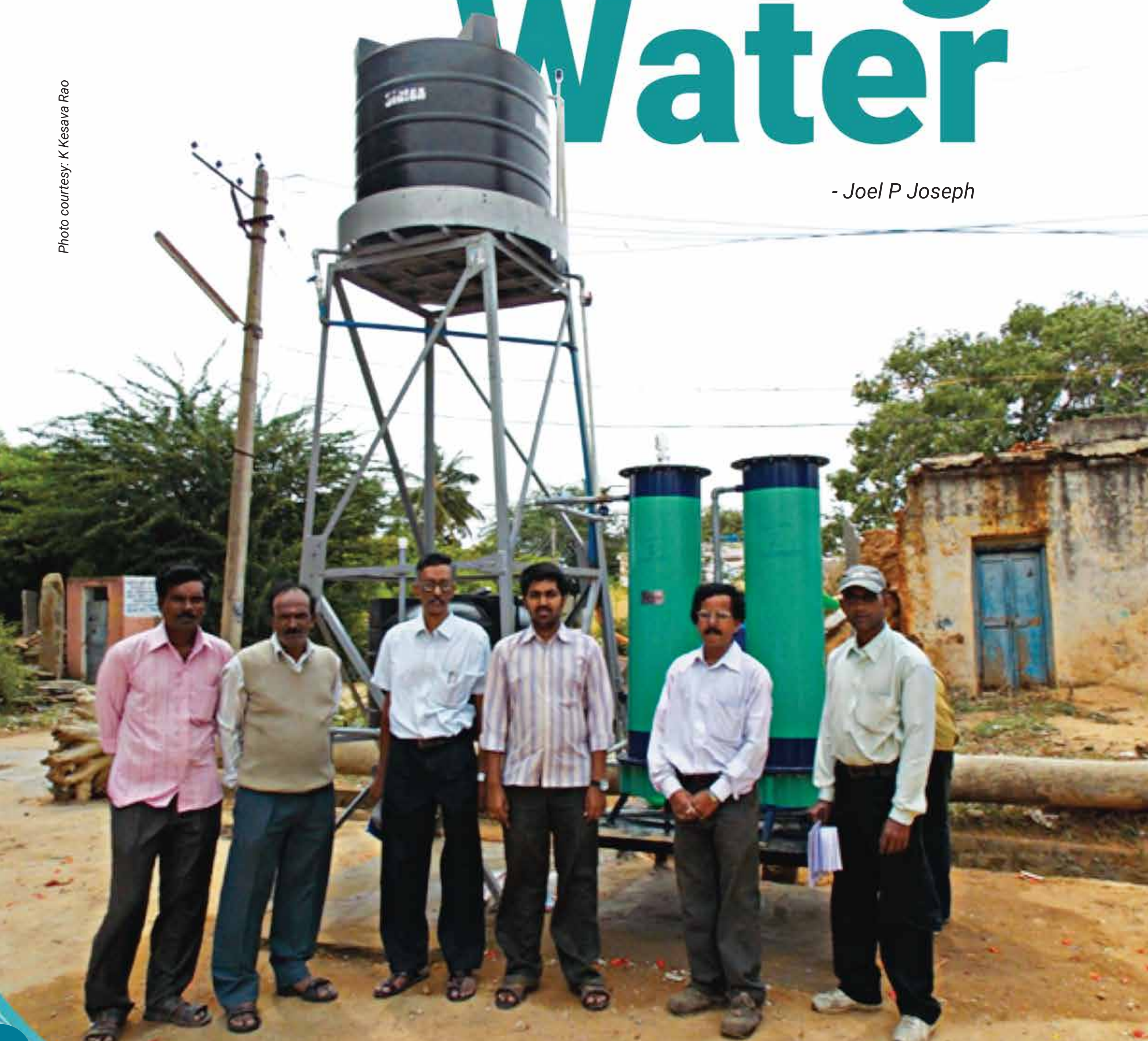
Both Ramananda and Shiba emphasise the need to probe deeper into understanding the links that thread together river ecology and chemistry with climate change. With this in mind, they plan to continue to delve into related facets in other rivers too, like the Godavari in peninsular India. "It is important to understand the variations that occur in river chemistry naturally over time, so we can identify the signals that we intercept because of human activities," elaborates Ramananda. He is also optimistic about the future. "Hypothetically, if no more pollutants are added to the river, the water flowing in the river would be cleaned by the following year's monsoon or at least be significantly diluted."

Anusha Rastogi is an Integrated PhD student in the Division of Biological Sciences and a former science writing intern at the Office of Communications, IISc

In Search of Drinking Water

- Joel P Joseph

Photo courtesy: K Kesava Rao



The community-level defluoridation plant at Yellampalli. Kesava Rao (third from left), Naga Samrat Maruvada (fourth from left) and their assistant Mahadeva Rao (second from left) can be seen along with the technicians who installed the unit

Researchers at IISc are working on innovative solutions to improve water quality

In August 2011, K Kesava Rao, Professor at the Department of Chemical Engineering, visited the village of Yellampalli, about 100 km north of Bangalore. The residents of the village were faced with a huge problem: water scarcity. To make matters worse, the available groundwater seemed contaminated. The government had set up a reverse osmosis plant to deal with the problem, but the reject water formed a pool nearby, seeping into the ground and cycling back as groundwater. The cattle that drank water from the pool were falling sick, and the elderly who drank the groundwater complained of joint pains.

The team from IISc led by Kesava intended to treat this reject water. “When we first visited the village, we saw that the children at the government school near the Panchayat Office had brown teeth,” says Naga Samrat Maruvada, a former PhD student of Kesava. “We could see signs of dental fluorosis.” Kesava and his group went on to set up a community-level plant to remove excess fluoride present in water.

Fluoride is one of the major contaminants of drinking water. Besides such ions, other contaminants include microbes, heavy metals, and toxic chemicals. According to the World Health Organisation (WHO), contaminated drinking water causes more than 5 lakh deaths each year.

An expert in granular flow, Kesava made his foray into water treatment with a desire to make some social impact through his work. “I used to read newspaper reports about problems with water contamination, particularly excess fluoride in water, and wanted to do some applied research that would benefit people,” he says. Thus, Kesava collaborated with a friend, Arup K SenGupta, Professor of Civil and Environmental Engineering, Lehigh University, USA, to set up the community-level defluoridation plant at Yellampalli in order to treat the reject water from the existing reverse osmosis unit. Arup had earlier developed an adsorbent to remove arsenic from contaminated water, and the duo wanted to use the same technique at Yellampalli. “It was a polymer resin with zirconia nanoparticles in it,” Kesava says.

As Kesava and his colleagues later found out, treating this water was more complicated as it was rich in other ions like nitrite and nitrate ions. Moreover, the anti-scaling agents used in the reverse osmosis plant corroded the columns of their defluoridation plant, causing the water to leak. Kesava and Arup then decided to abandon the project.

Kesava’s group would eventually go on to pursue the idea of removing excess nitrogen from water when Maruvada received an Erasmus Mundus fellowship. As part of this project, they developed a microbial fuel cell containing a microbe found in seawater to remove nitrogen.

Kesava and his friends, Seth H Frisbie and Michael W Prairie, at Norwich University, USA, recently developed a low-cost spectrophotometer – a device that detects components in water by measuring the amount of light of a specific wavelength passing through it – that could detect fluoride, manganese, and iron in water. The device, which cost USD 63, was tested successfully both in the US and India. The idea was an outcome of discussions during a water conference that was held at IISc. In fact, Kesava’s journey in water research came full circle with this project, as his first project in the field – before the Yellampalli project – was to develop an LED-based spectrophotometer to estimate fluoride levels in water. This was a collaboration with his friend Govind Rao, a Professor of Chemical, Biochemical, and Environmental Engineering at the University of Maryland, Baltimore County, USA. Kesava and Govind, who do not like the idea of patenting products that benefit society, have detailed the working of the instrument they developed in a paper they published in the now defunct journal *Field Analytical Chemistry and Technology* in 2008. Similarly, Prairie and colleagues also published the details of the instrument he recently developed in *PLOS One* in 2020.

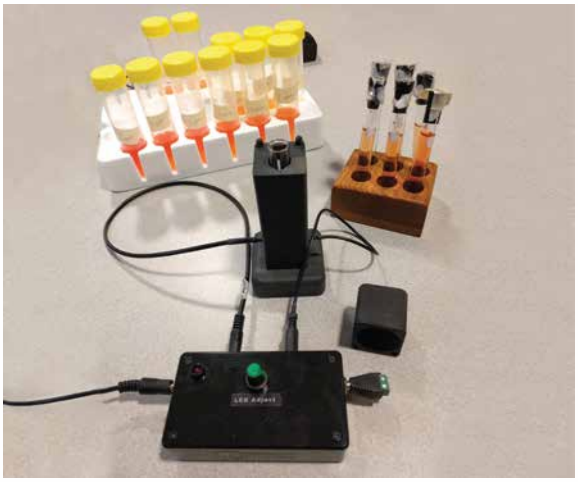


Photo courtesy: Michael W Prairie

The LED-based spectrophotometer to detect the levels of fluoride, manganese, and iron in water

Another recent effort to remove contaminating ions from water has come from the lab of Partha Mukherjee, Professor at the Department of Inorganic and Physical Chemistry. His group has designed a molecular nanocage that selectively removes fluoride from groundwater. “Each cage can bind to six fluoride ions,” Partha explains. The group is continuing to work on developing cages that can bind to other anions like chloride. “Chloride is a major issue in the treatment of industrial wastewater, especially in steel industries, where the wastewater can corrode steel,” he says. Although the method has only been tested at laboratory scale now, they are interested in engaging with people who may want to scale this technology up.

One limitation of the method, as Partha explains, is that these cages dissolve in water. “One way around it is to use these cages in columns so that the cages can be recovered easily after treating water,” he adds. Earlier, Partha’s lab had also developed a compound that kills bacteria in water.

Such technologies are the need of the hour as more than 700 million people live in countries with high and critical levels of water stress. Moreover, at least 3 billion people are unaware of the quality of water they use owing to a lack of monitoring. These growing concerns about water scarcity and contamination have led the United Nations to lay out a Sustainable Development Goal (SDG) to “ensure availability and sustainable management of water and sanitation for all.” At the national level, the National Green Tribunal (NGT) established more stringent norms for water quality, proposed by the Central Pollution Control Board (CPCB) in 2015. According to the norm, Chemical Oxygen Demand – a measure of organic matter present in water represented as the amount of oxygen needed to oxidise them – was restricted to 20 mg/litre; Biological Oxygen Demand – the amount of oxygen consumed by microbes while they decompose organic matter at a specific temperature – at 10 mg/litre; and the total nitrogen level at 20 mg/litre.

These revised, more stringent, guidelines that the NGT then enforced also provided the motivation and thrust for the work of Sanjiv Sambandan, Assistant Professor at the Department of Instrumentation and Applied Physics. When Sanjiv started his independent research group in IISc in 2010, he noticed that there were several technologies to treat water that went into homes for usage – technologies that take, say, contaminated tap water and improve its quality. “But there was nothing much being done about water going out of a house or industry,” Sanjiv says. Having identified this gap, he started exploring ways to “reclaim water and reuse it – if not for drinking, at least for things like landscaping, washing cars, and so on.”

Traditionally, such wastewater that was let out of a house or industry was finally treated at a centralised Sewage Treatment Plant (STP). These plants are typically run using techniques that involve the use of microbes along with chemicals and membranes to treat water. Such treatment technologies that use chemicals or membranes pose a logistic barrier as one has to procure and store them, Sanjiv explains. Besides, its use and maintenance also requires expertise.

Under the revised guidelines, first, the Pollution Control Board ordered that all water treatment be decentralised. Incidentally, Sanjiv’s group was working with this thought in mind, envisioning a technology for decentralised water treatment, while avoiding the pain points of using membranes and chemicals, and the requirement of expert maintenance for the treatment process. They used the concept of electrocoagulation — a technology where two plates are placed in water and DC voltages applied to facilitate an electrochemical reaction. “The positively charged metal ions would neutralise all anionic pollutants and Van der Waals forces coagulate these pollutants. This is like an electronic alum,” Sanjiv explains. His group modified the system to include the use of controlled pulsed current along with using the geometry of curved plates to enhance coagulation.

Photo courtesy: Openwater

The mobile wastewater treatment unit of Openwater

Second, NGT made water treatment norms more stringent, which many STPs were struggling to meet due to fluctuating water load and poor maintenance. In addition to much higher water quality that the technology provides, it costs less than what an STP would cost. “The technology is modular, does not require any civil construction, and can be easily deployed at different sites,” says Prabha Nagarajan, Director of Openwater.in, the start-up that Sanjiv founded with this technology.

The technology has gained quite some traction and won several awards. They have started deploying units in a few sites in Bangalore and are running a social impact project as well. Through the start-up, Sanjiv and his colleagues are looking at developing new products and taking their current product to the market.

“What came out from my lab is the technology, a basic idea. But there are a lot of steps involved in launching a product, and that comes with industry experience. We have our directors, Prabha Nagarajan and Nitin Parekh, who do that very well,” Sanjiv says.

A talented and enthusiastic team of scientists, engineers, designers, fabricators, and an administrator works shoulder-to-shoulder with the top management out of a container located close to the STP at IISc, innovating new products and designs to meet the market’s needs. “I am grateful to our excellent team of engineers who have made all this possible,” Sanjiv says.

Although their product is close to drinkable quality, Sanjiv and team do not make the claim. “Our technology cannot bring down the levels of dissolved solids in water to below 50% of input levels,” Sanjiv says, explaining the limitation of the technology.

“If potable water is required, we could consider this as a pre-treatment step,” Sanjiv says. “This could do all the heavy lifting before it is connected to a reverse osmosis line to make it drinkable,” Prabha adds.

In keeping with their vision of providing clean water for all, Openwater is working on a social impact project at Mavallipura, a village about 20 km north of Bangalore city. The quality of groundwater here is extremely poor due to poor solid waste management of the landfill next to the village. The waste leaching from the landfill has contaminated the water sources that the residents use. Sanjiv and team hope to provide clean, reusable water for the residents of Mavallipura using their water treatment technology.

Joel P Joseph is a PhD student at the Centre for BioSystems Science and Engineering (BSSE), and a former science writing intern at the Office of Communications, IISc

Photo: Joel P Joseph

Team Openwater at their workstation in IISc

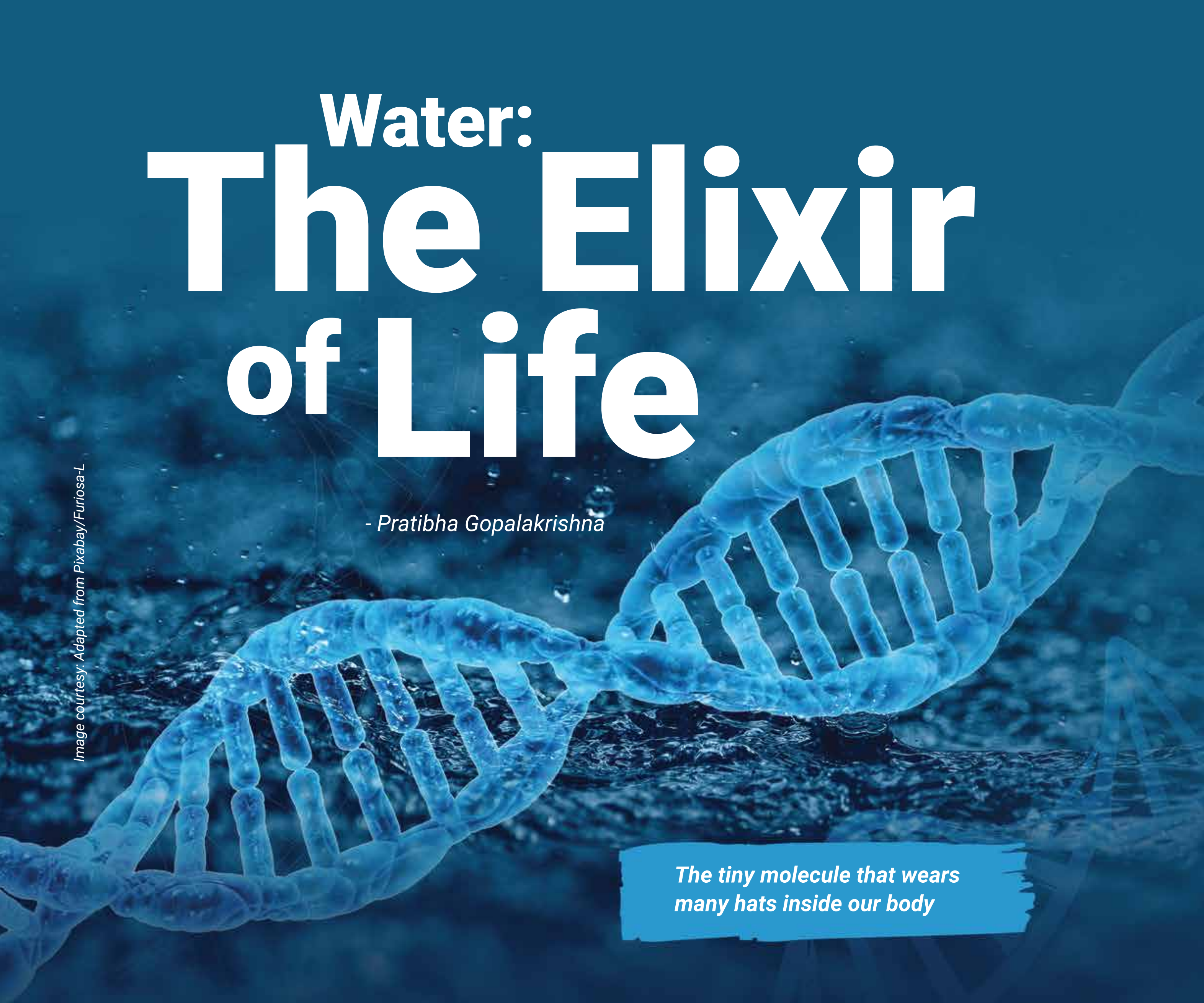


Image courtesy: Adapted from Pixabay/Furiosa-L

Water: The Elixir of Life

- Pratibha Gopalakrishna

The tiny molecule that wears many hats inside our body

A memory brings a smile as I gulp down water to quench my thirst. School, science class, and tiny desks. Our teacher was explaining to us that "water is colourless, odourless, and tasteless." "But miss, I can taste water!" one of my classmates piped up, as our little minds took in this information.

One of the first liquids we are taught about at school, water, is dubbed as the 'universal solvent'. Water is, in fact, an outlier among liquids in terms of its properties. Made of just two hydrogen atoms and one oxygen molecule, water is not an inert compound, but a most extraordinary substance. It wears multiple hats inside our body because it transports, lubricates, reacts, enables, stabilises, signals, structures, and partitions. Without water, the cells in our body would stop functioning. Martin Chaplin, emeritus professor at the London South Bank University says in his book, *Water: The Forgotten Biological Molecule*, that we need to think of the living world as an equal partnership between biomolecules and water where each is required and structured by the other.

In our body, water interacts with other biomolecules like proteins, lipids (fats) and even DNA – it wedges itself between the helical grooves of our genetic material. Not only do we know that water controls the DNA structure, but we also know that it actively plays a role in protein synthesis. It also sticks to the surface of proteins, forming a shell. Water acts as a 'proofreader' to make sure there's no error in the protein that is synthesised from the DNA skeleton. Even RNA requires a steady supply of water to function at its optimal capacity.

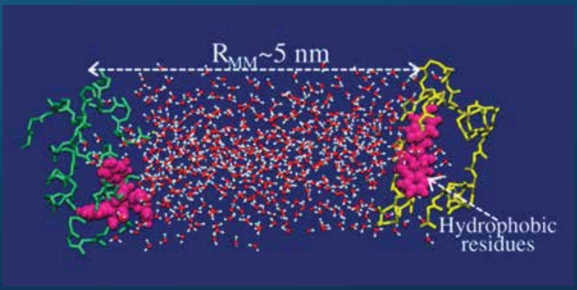
It is extremely difficult to directly observe how water interacts with other molecules inside a human body (for obvious reasons), but this hasn't deterred two scientists at IISc: one who has pioneered biological water research and one who is interested in detecting water molecules moving through the brain.

And then there were ten

"For a molecule of such small size and low molecular weight, water is quite remarkable. Evolution of life on Earth is, to a great extent, driven by water," says Biman Bagchi. An Honorary Professor at the Solid State and Structural Chemistry Unit at IISc and a DST-SERB National Science Chair Professor, Bagchi has been researching water's role in the human body for the past 25 years. He says that he coined the term 'biological water' in his 1997 paper where he describes that water near protein surfaces behaves differently from normal water due to the hydrogen bonds between the water and protein. While his terminology received some criticism initially, he says that it was eventually accepted and now, 'biological water' is used frequently in medical literature and in biology. Bagchi and his team have focussed on studying how water interacts with proteins.

For instance, insulin, an enzyme that is produced in the pancreas, is usually stored as an inactive hexamer (six protein chains bound together). Secreted by the pancreas, insulin separates into dimers, containing two protein chains, and when the need arises, these dimers split to form monomers. This splitting is important as our cells respond only to the monomeric form of insulin, and water helps to do this by moving in between the two protein chains to break the dimer.

Image courtesy: Banerjee et al., PNAS, 2020



Insulin dimer dissociation where monomers are solvated by water

Another role played by water is in stabilising the insulin hexamer itself. The six protein chains are held together by 10 water molecules. "It's amazing … like the novel *Ten Little Indians*," Bagchi says, referring to the famous mystery-thriller novel by Agatha Christie. Remove these 10 molecules from the picture and the insulin hexamer breaks down to clumps, he adds. This shows that water is integral to the structure of insulin.

Water also helps to break the hydrogen bonds in myoglobin – haemoglobin's distant cousin that supplies oxygen to muscle cells – thereby, helping the protein unfold. "This is what I call the functional role of water," says Bagchi, adding that more emphasis should be played on these aspects, and that scientists have only recently begun to understand these complex roles of water in biology.

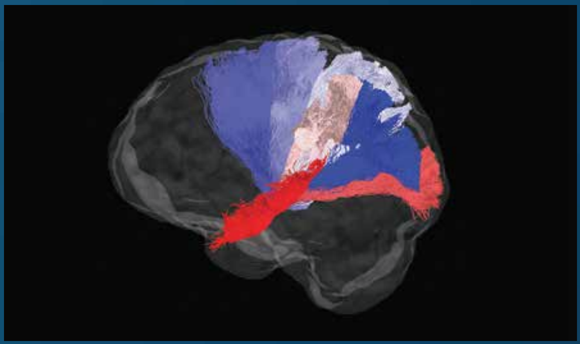


Image courtesy: Varsha Sreenivasan and Sridharan Devarajan

The image shows connections between the midbrain and various regions of the neocortex. Connections to each region are shown in a different colour, and were all estimated with diffusion MRI and tractography in the living human brain

Tracing water in our brains

Water is also helping scientists study the extremely complex structure that is our brain. Sridharan Devarajan, Associate Professor at the Centre for Neuroscience, IISc, studies computational brain models to figure out what goes on in our brains when we are attentive and when we make decisions. One of the techniques Sridharan uses is dMRI (Diffusion Magnetic Resonance Imaging), which detects the movement of water molecules along particular directions by applying a magnetic field. "The equipment exploits the resonance of protons in the brain," he explains. This allows scientists to track the movement of water molecules to which these protons belong.

The brain is made up of nerve cells – long thread-like structures that can clump together to form nerve fibres. Each nerve cell has a tail-like filament called the axon that is covered by a fatty sheath called myelin. His group tracks the diffusion of water through these axons in the brain. "Water is among the most abundant molecules in the brain, and is therefore easy to track," Sridharan says. Just like electricity travels only inside a wire along its length and not outside, as the wire is insulated, water moves only along the length of the fibre bundles and not as much across, because of the fatty sheath covering the fibres.

Advanced algorithms can track this movement along the bundles and permit the mapping of neural connections between different areas of the brain. This is similar to tracking which direction cars move in, and using that information to map the roads in a city. With this approach, Sridharan hopes to find out how different parts of the brain "talk" to each other.

Such studies are also important for understanding brain dysfunction – how broken connections between different parts underlie neurodegenerative disorders such as Alzheimer's and Parkinson's disease. But despite decades of research, there are still many, many mysteries yet to be unravelled. And the clues might very well be hidden in this tiny molecule – the colourless, tasteless and odourless water, which is the elixir of life.

Cleaning up the keres

- *Narmada Khare*

Restored Yelahanka-Puttenahalli kere

What it takes to recycle sewage and rejuvenate the city's lakes

In 1993, when I first visited Bangalore, it felt like a different country to me. I was coming from dry and hot Nagpur, where the sky fades to almost white in summer, and the colour of the Gulmohar flowers is yellowish orange. Here, the trees seemed larger and greener, the Gulmohar blossoms flaming red, and the many water bodies inside city limits gave it a fantastical feel. I returned to Bangalore in 2014 for work. Many of the old landmarks were gone. Bulky flyovers shrunk the skies to narrow strips, and the traffic was unbearable. But the lakes were still there. In fact, I passed three of them every day on my way to work.

I was soon to find out that all wasn't as it seemed since my last visit. Between 1993 and 2014, several of the lakes had been destroyed in an attempt to accommodate the city's growing population. The water in others was contaminated with untreated sewage, and had become unsuitable to support life. Researchers, including those at IISc, have been reporting on these 'decaying lakes' for years. But little seems to have improved.

Lakes, cities and urbanisation

According to the records of the Bangalore Water Supply and Sewerage Board (BWSSB), most of the lakes in Bangalore are not fed by natural streams. The oldest among them were constructed during the 16th century to capture rainwater. This was the need of the hour for a growing and land-locked city without any river. These lakes, or 'kere' in Kannada, took care of the water requirement for drinking, irrigation and fishing. Yet, because of the topography of the city, they also accumulated wastewater from the surrounding localities. When the population was still small, this didn't pose a big problem.

Most ancient cities were built along rivers. Rivers carried away their refuse, diluting it along the way. Ruins of cities of the Indus Valley Civilisation, like Harappa and Dholavira, have elaborate, thoughtfully-designed networks of water and wastewater channels. Remains of terracotta pipes, storage tanks and baths suggest that water was brought in from the nearby rivers and moved around the city using natural slopes. The used water was then taken out, back to the waterbody downstream. Initially, with smaller populations and larger distances between cities along their banks, rivers acted as natural sewer systems. Waste from one city settled down, got filtered through sand-beds, and water was clean when it reached the next.

In modern times, as cities swell under the pressures of urbanisation, spaces separating them are beginning to vanish. Garbage is piling up on roadsides at an alarming rate, attracting disease, emanating foul smell and giving rise to ugliness. Overuse of water has pushed the groundwater levels deeper. Water requirement has increased enormously, and humans are learning the hard way that it is not an unlimited commodity; that water, once used, needs to be purified before recycling it or returning it to the environment. Land-locked cities like Bangalore are already importing large quantities of water from Mysore, and producing just as much sewage.

Treating sewage: the process

'Sewage' is the term used collectively for wastewater from households (mixed with food particles, cleaning products, urine and faeces) and industries (mixed with chemical waste), with hospitals, schools and residential areas also contributing to it.

Sewage is passed through several levels of treatment. Solids that can be filtered or sedimented are removed first (primary level), and what remains is 'sludge'. Dissolved organic compounds from the sludge are decomposed next, with the help of microorganisms in the presence of oxygen (secondary). More complex techniques are needed to remove nitrates and phosphorus (tertiary). The removal of compounds that use up oxygen present in water or removal of Biochemical Oxygen Demand (BOD) is necessary to make water life-sustaining. The goal is to have water that looks and smells clean, is devoid of pathogens, and has enough dissolved oxygen to support a healthy ecosystem.

Giving value to sewage

IISc's contributions to wastewater treatment and recycling commenced in 1916 with the arrival of sanitary chemist Gilbert Fowler, who was appointed the head of the Department of Applied Chemistry. He had a unique perspective on the sewage treatment process. HN Chanakya, a former Chief Research Scientist at the Centre for Sustainable Technologies (CST), says, "When he came to India, Fowler was interested in *utilising* waste. That was a paradigm shift. In those days, waste was something to be gotten rid of. And unless you treat waste, give it value, there is no point in bringing it back into circulation."

Fowler had helped develop the Activated Sludge Process (ASP), a method most prevalent then as it is now, even before he landed in India. It needed air to be forced through filtered raw sewage for days, allowing existing oxygen-loving microbes to digest the organic matter. The sewage thus treated was then allowed to stand, and cleaner water was separated. During a visit to the USA, Fowler realised that the success of this process depended upon the presence of the 'correct' type of bacteria. He showed that adding some of the old sludge to the new batch of sewage sped up the process and made it more effective. He also showed that treated sewage became rich in nitrates and could be used in agriculture. His work was in great demand all over the country and the world, as outlined in IISc's 1916-17 Annual Report.

Fowler became the first Chair of the Department of Biochemistry in 1921, and built an activated sludge plant to deal with the sewage on the IISc campus. After his retirement, V Subrahmanyan and SC Pillai, both professors in the department, also made notable contributions to sewage research. In the early 1940s, they published several papers showing unambiguously that more than bacteria, single-cell organisms like *Vorticella* and *Epistylis* were responsible for purifying sewage in ASP. They created large aggregates or 'flocs' that trapped contaminants and separated them from wastewater.

Going beyond conventional clean-up

More than a century since Fowler's time, researchers at IISc have continued to work on treating wastewater. One of them, Lakshminarayana Rao, Associate Professor at CST, is using a new approach: bringing lightning into the lab.

When lightning strikes in nature, the air in its path becomes plasma, a state of matter much more reactive than any gas. And when lightning strikes water, the composition of water changes. This plasma activated water (PAW) has several applications in medicine and agriculture.

Rao describes the process of creating PAW as passing electricity between two electrodes, the anode being a metal and the cathode being water. "If you apply enough voltage, you have breakdown of the air, and you start having a small arc between the anode and the cathode. This arc, depending on how you operate it, can render the water below rich in certain compounds or elements like nitrogen."

Although PAW can efficiently destroy pathogens in water, it has not yet been used for large-scale wastewater treatment. It is a niche, tertiary level of treatment, recommended for small-scale recycling units in apartments or isolated communities. It uses ozone gas for the creation of plasma. Rao says, "Our lab builds ozonators that generate ozone directly from air. This is a highly oxidising chemical, and when you bubble it through secondary treated water, it disinfects it – makes it free of pathogens, colour and odour. Such water can be used for gardening or cleaning purposes." Rao's team has already installed plants using this technology in some schools and apartment complexes, and his goal is to expand it to the village level.

Another young scientist preparing to work on tertiary level sewage treatment is Sreenivasan Ramaswami, a newly joined Assistant Professor at CST, who has named his research group 'SusPaani'. A chemical engineer, Sreenivasan believes that several of the challenges in removing the pollutants from water need sustainable biological solutions.

"Micropollutants – also called emerging contaminants – are a group of compounds that remain in wastewater that has already gone through the conventional treatment processes," he explains. "They do not degrade in the conventional activated sludge process, and thus end up in the receiving water bodies." These are organic, non-biodegradable compounds that come from our medicines, personal care products, and household and industrial chemicals. If – or when – these compounds reach water bodies, they can have disastrous effects on aquatic and other higher organisms.

"They can be mutagenic to aquatic organisms. There are studies that found male fishes becoming female, fish having problems with their eggs, neural development and so on. To protect the environment, we must treat the wastewater further," he adds. "Internationally, researchers are trying to degrade them or remove them by physico-chemical methods. I want to solve this biologically, which I think will be more economical and efficient." Sreenivasan is planning to work on enhanced biological degradation of organic micropollutants using biofilm reactor systems.

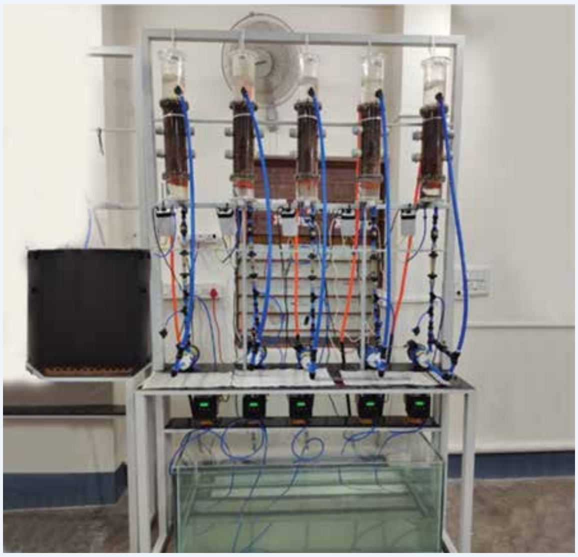


Photo courtesy: Sreenivasan Ramaswami

Experimental setup containing a series of fixed-bed biofilm reactors

Reviving Kolar valley

The wastewater-related work that IISc researchers are doing is more than merely academic. Rao and Chanakya have also been working with government authorities in maintaining the keres, designing and installing Sewage Treatment Plants (STPs), and planning the replenishment of water bodies in Bangalore and areas surrounding it.

"Bangalore receives close to 1,440 million litres per day (MLD) of freshwater from the Cauvery, which is in Mysore," Rao explains. "Together with borewells, Bangalore consumes about 1,800 MLD of water. Out of this, 80% gets collected and treated, and 20% is lost. In all, the city generates 1,500-1,450 MLD of sewage daily."

Rao is part of a team of IISc professors that advises, provides technical support, and monitors sewage treatment and recycling schemes undertaken by the Government of Karnataka. He talks about the KC Valley project, considered one of the success stories. It started in 2018 with an aim to help Kolar, a city 70 km to the east of Bangalore. Kolar had suffered from drought for almost a decade, and its keres were completely dry. The idea was to pump treated wastewater from Bangalore's STPs up to higher elevations near Kolar and release it there. The water would then flow through natural terrain, getting cleaner as it flowed, and drain into the keres in Kolar. "The scale of the project was 440 MLD, almost one-third of Bangalore's wastewater production, and it filled 137 tanks in Kolar."

When the project went through certain legal troubles, Rao and others made a presentation to the Supreme Court explaining the scientific merits of the project, and demonstrating that the water reaching the keres in Kolar was safe to use in agriculture and industry for purposes other than drinking. Rao adds that the project has made a huge difference in just four years. "The underground water tables have risen up from 1,800 feet to less than 100 feet! Huge improvements are seen in agriculture, and the rural economy is on the way to revival. Milk and flower production have gone up. People who were doing meagre jobs in Bangalore have gone back to Kolar."

Photo: Seema Sukhani

Students and residents clearing the kere of heavy foliage

Bringing birds back

Keres in Bangalore too need help, and smaller STPs have been set up to clean the incoming sewage and replenish lakes like the Yelahanka-Puttenahalli kere.

"Like most tanks of Karnataka, the Yelahanka-Puttenahalli lake is fed with run-off, and at just about 2 m deep, much of the water evaporates, and the lake used to dry up by January-February [every year], often leaving only a tiny pool of water for water-birds," says Chanakya.

Photo: Seema Sukhani

Weed being lifted using JCB, leaving behind clean water

Once a safe haven for many species of birds, the kere was engulfed by the growing city in the first decade of the century. It began receiving untreated domestic and industrial sewage around 2013, resulting in severe eutrophication – heavy growth of aquatic plants because of progressive accumulation of nutrients, particularly nitrogen and phosphorus. This disproportionate amount of nutrients resulted in the rapid growth of algae and aquatic plants, choking the ecosystem. Biodiversity decreased, and the overgrown algal layer reduced the amount of sunlight and oxygen penetrating the surface of water. The number of bird species reduced drastically as their nesting area became uninhabitable.

Residents of the area, working with the Lake and Bird Conservation trust, requested researchers like Chanakya to help find a solution. The lake had not seen much fresh rain water in previous years, and was basically full of sewage and weeds. Chanakya and his team studied the experiences of other lake restorers before making a plan to rejuvenate the ecosystem in and around the kere.

There were three aspects to the project: removing the weeds that choked the lake, ensuring a constant supply of clean water all through the year, and creating adequate living conditions for organisms at all stages of the food-web – from algae at the bottom of the web to the birds at the top. Chanakya explains, "[We wanted] to make this lake suitable for three types of water birds – waders, swimmers and divers – and two types of nesting birds – local and migratory. We needed a different geometry of the lake compared to [what was done in] previous lake restorations where the lakes were restored to a uniform water depth of 2 m or more." They decided to establish a gradually sloping bottom for the lake, which would create habitats for different varieties of fish that would feed on a gamut of algae and zooplanktons.

To keep the water quality clean, the Chanakya's CST team designed and helped the Karnataka Forest Department (KFD) in setting up a Passive Sewage Water Treatment (PSWT) plant at the deep end of the lake. Almost 1 MLD sewage diverted from the city was passed through this system. The treatment was at three levels, using different types of biological reactors, till more than 95% organic matter and 80% of nitrogen and phosphorus were removed. It was also decided that only as much sewage would be drawn into the lake as the amount of water evaporated during the day. This ensured that the kere didn't dry out in summer, and could accommodate rainwater during the monsoons. Seema Sukhani, one of Chanakya's graduate students, was deeply involved with this project. In a speech during the 2022 Kere Habba, she mentions that she felt as if she grew up with the lake. Her commitment is also acknowledged by Chanakya when he remembers how she used to leave her hostel at 5 am to go collect water samples from Yelahanka for analysis.

This restoration project required a lot of person hours, and Chanakya remembers the huge contribution made by the residents and youngsters in the community as well as his own students. Employees of KFD also pitched in during the pandemic, when the residents could not participate. This was a true collaboration between the scientists, the governing body and the citizens, says Seema in her speech. And the fruit of their labour? Birds have now started returning to this kere for the first time in years.

A Day in the life of an Assistant Project Engineer

- Ranjini Raghunath

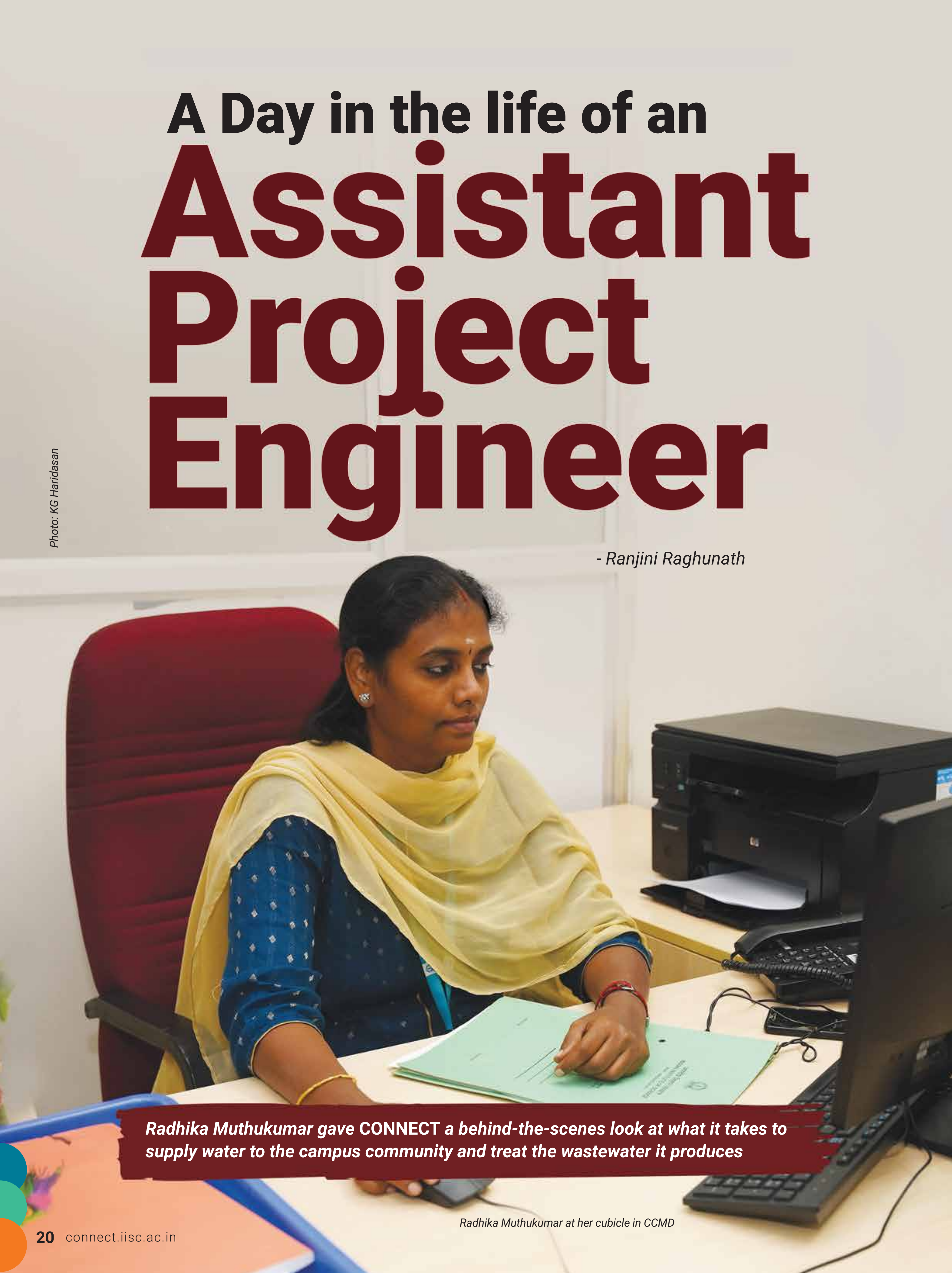


Photo: KG Haridasan

Radhika Muthukumar gave* CONNECT *a behind-the-scenes look at what it takes to supply water to the campus community and treat the wastewater it produces

Radhika Muthukumar at her cubicle in CCMD

A few metres down the road from IISc's main gate is an 80-year old building that was designed by Otto Koenigsberger, an architect who left Nazi Germany and worked for the Mysore State in the 1940s. Its wing-like porch canopy is quite distinctive, and embedded in its central section is what was once India's first wind tunnel. Today, this vintage building is also the home of IISc's Centre for Campus Management and Development (CCMD), where Radhika Muthukumar works.

Radhika is an Assistant Project Engineer at CCMD. She joined IISc in April 2019 after working at the National Thermal Power Corporation Limited (NTPC) for more than 13 years. At CCMD, she is responsible for overseeing the campus' water supply systems as well as the Sewage Treatment Plants (STPs).

Today is the first day of August and a Monday. Radhika begins work at around 9.30 am by checking her emails for water-related complaints from the campus community. The Institute has an online portal called Samadhan for complaints related to civil, water or electrical issues. An external agency has been deputed to respond to routine problems raised through the portal. Any major issues that they are unable to handle get forwarded to Radhika. She typically gets about 5-10 complaints in her inbox a day, mostly related to water leakage.

Radhika's actual day begins much earlier. She and her husband get up at 4.30 am to send her 5-year old son and 10-year old daughter to school by 7.30 am. Once the kids are off, she gets on her scooter and rides down to the campus from her home near the BEL circle. Today, her daughter is unwell and has stayed home from school, so in between responding to emails, she calls and checks in with the nanny who's at home.

Radhika's cubicle is on the ground floor of the CCMD building. Past the entrance to the left is the office of the Project Engineer and Estate Officer (PE), who heads the Centre, and beyond this is a passage on the left leading to the cubicles where the assistant project engineers sit. There are about 30 staff members working at CCMD. Apart from the project engineers, there are also administrative staff members, project associates and technical assistants on contract.

At CCMD, Radhika manages various civil engineering projects, mostly related to water supply. This includes reviewing the project specifications, preparing the plans, uploading tender documents, working with contractors, monitoring the progress of projects, and ultimately seeing the project to its completion. An external agency called Eco Protection Engineers has been recruited by the Institute to manage the water supply round the clock, with about three or four staff members in each shift, who report to a site engineer.

Photo: Ranjini Raghunath

Radhika with Sachin Kumar, one of the site engineers at CCMD

Sachin Kumar, one of the site engineers, stops by. Radhika discusses with him the pending complaints from Friday and informs him of a new complaint raised by one of the residents in the faculty quarters. She also reminds him of two estimates that need to be prepared for upcoming waterproofing and drainage related work at the Biological Sciences and the Physical Sciences buildings. She then calls the nanny again and learns that her daughter has been vomiting, so she asks the nanny to give her some lemon juice.

This morning, Radhika also gets a visit from staff members at the nursery. B Sridhar, who was in charge of the campus nursery, retired the previous week, so she has temporarily been assigned its charge. The staff members brief her about the number of people who work at the nursery, and about what they do. Radhika's workload has increased during the past few weeks. One of the other assistant project engineers who was temporarily deputed by the Public Works Department went back to his organisation, and the projects he was handling were distributed among the other engineers. Apart from her own work, Radhika is now also managing some of the construction projects near the D gate.

During the day, she also makes it a point to go around the campus, visiting various pump houses and the STPs. There are about 35 pump houses which supply water to most of the buildings. The Institute's water consumption is enormous – about 2 million litres per day – which is

almost entirely supplied by the Bangalore Water Supply and Sewerage Board (BWSSB), and is routed to various departments and residences through these pump houses. Around 11 am, she sets off.

Pumping water

The first visit is to the one of the oldest pump houses nestled between the Department of Organic Chemistry and the Interdisciplinary Centre for Water Research. It is the second largest on campus, with pumps of 10 HP capacity supplying water to several departments on this side of the campus as well as the housing colony. The reservoir next to the pump house is capable of holding about 4 lakh litres of water. There is one technical assistant on site, cleaning. He also keeps watch over the sensors that display the water and energy levels.

Next is a visit to the campus' largest pump house which is located at the southeast end of campus, where the Department of Mechanical Engineering's old Thermal Power Station used to be. There are two pumps of 40 HP capacity and two large reservoirs that can hold about 3 lakh litres of water each. There's also an overhead tank to which the water is pumped before being supplied to the nearby departments. When Radhika joined, several of these reservoirs didn't have proper concrete covers; she took the initiative to get them all fully covered, she explains. A direct line from the BWSSB supplies water to these reservoirs.

Photo: Ranjini Raghunath

The campus' largest pump house located behind the Department of Mechanical Engineering

The BWSSB staff have always been supportive and helpful, Radhika says. They are usually prompt in responding when there's an issue with water supply or when the subway gets flooded during the rainy season. Passing the subway on the way back to CCMD, and past the demolished Prakruthi canteen, she remarks that she misses the vibrant environment the eatery used to offer for people to sit and chat.

Photo: Ranjini Raghunath

The centralised control room where water levels at various pump houses are monitored

Before heading back to CCMD, she stops by the building behind the Students' Council which houses a centralised water supply control room fitted with SCADA (Supervisory Control And Data Acquisition), a software platform that enables continuous data collection and monitoring. She explains that about 30 pump houses have been fitted with automatic sensors that feed data about water levels into this system, which appear on a computer screen that one of the site engineers constantly monitors. There are also automated alarms that go off when the water supply gets cut off. This was completed as part of a Rs 4 crore water management project launched in 2019 by IISc. The second phase of this project will start soon, she says.

Back at her desk, the nanny informs her on the phone that her daughter is still a bit feverish. One of the site engineers then comes by with a work order drawn up for building and painting a partition wall at the Chemical Sciences building. She asks him to get some clarity on the area mentioned before putting it up for approval by the PE.

For small projects like these, Radhika explains, CCMD has the discretion to appoint any registered contractor. For larger projects that cost more than Rs 2.5 lakh, a bidding system has to be followed where tenders are called for from authorised agencies via the Government's centralised eProcurement System, and the lowest bidder needs to be awarded the contract. One such project coming up is the second phase of the water management project she mentioned. It will involve not only replacing some of the old water pipes and installing sensors in the remaining pump houses, but also fitting smart water meters across campus. When Radhika joined IISc, she noticed that there were some errors in the bills being paid by IISc to BWSSB.

Due to her efforts and consistent follow-up, the Institute was able to significantly reduce the amount paid against the water bill, she says.

Radhika usually cooks and brings her own lunch from home. Today's lunch is rasam rice and spinach. While eating, she likes to browse courses on the online learning platform Coursera. She had long dreamt of pursuing higher studies but didn't get a chance to do so earlier because she took up a job right after her BE degree. This week onwards, she is starting an MTech degree programme in online mode from BITS Pilani. The classes will be held for eight hours on Saturdays, something she's eagerly looking forward to. Eventually, Radhika also hopes to become accredited by the US Green Building Council, and apply for a WELL AP certification, which will allow her to better understand green building projects.

After lunch, she gets on her scooter again to visit the STPs.

Treating wastewater

There are two STPs on campus which recycle the wastewater from the hostels, residences and amenities buildings, which is then used to water the trees and plants across campus. The first STP she visits is located on the road leading from the Faculty Club to the D gate. Like the water supply, the task of managing these STPs has also been outsourced to an agency, called Global Tech Services. Two technical assistants are at the site. It is their job to jot down parameters like feed flow, air pressure, turbidity, pH, dissolved oxygen and so on every two hours. After inspecting their records, Radhika asks them if they are facing any issues. They mention that one of the flow meters is not working, so she will have to investigate and rectify the issue.

The STP recycles about 500 m^3 of wastewater per day. Apart from an aerated bioreactor tank where bacteria break down the organic matter, there is also a membrane tank where GE ZeeWeed ultrafiltration membranes are used to filter out suspended solids.

The next STP is located on the opposite side of the campus, behind the Divecha Centre for Climate Change. Radhika loves this section of her rounds because she gets to pass by one of her favourite spots on campus: the mini forest with its tall bamboos. She likes how some parts of the campus have retained their raw and wild nature.

On the road leading to the STP, Radhika points to a new building where SWaMII, the campus' solid waste management initiative, has just moved to. She had managed the construction of this building which was made almost entirely from recycled materials, even some old tiles taken from different buildings that were renovated on campus.

Photo: KG Haridasan

Radhika with Afsar, one of the STP operators, holding a beaker containing recycled water

The second STP also treats about 250-300 m^3 of wastewater per day. Apart from these two STPs, there is one Effluent Treatment Plant (ETP) near the Biological Sciences building and a new one coming up next to the new Chemical Sciences building.

Back at CCMD, the nanny informs her that her daughter is doing better and sleeping, and her son is back from school. The rest of the afternoon is spent in going over an agreement that needs to be signed with an architect for an upcoming project at one of the engineering departments. Radhika has to read through the terms and conditions thoroughly before it is uploaded on the tender website.

While she is working on the agreement, Bhavani, secretarial assistant at CCMD, stops by to check with her about the list of projects that will be put up for approval at the next Tendering Sub-Committee meeting. This committee meets every month to review and approve major civil projects on campus.

Apart from these committee meetings, Radhika and the other engineers also meet with the PE every Thursday to update him about the progress of their projects and the status of the complaints. She mentions that she misses the employee get-togethers and the professional development opportunities at her previous work place, but likes the fact that senior administrators are easily approachable at IISc. She feels happy whenever she sees a story about the Institute in the news.

By 5.30 pm, Radhika has finished making notes on the agreement and will discuss them with the site engineer tomorrow morning. After she heads home, the rest of the evening will pass by quickly as she spends time with her children, making dinner, watching some videos, and then tucking in early to get back up again at 4.30 am and begin a new work day.

GNR taught us to avoid the well-trodden path

- *Manju Bansal*

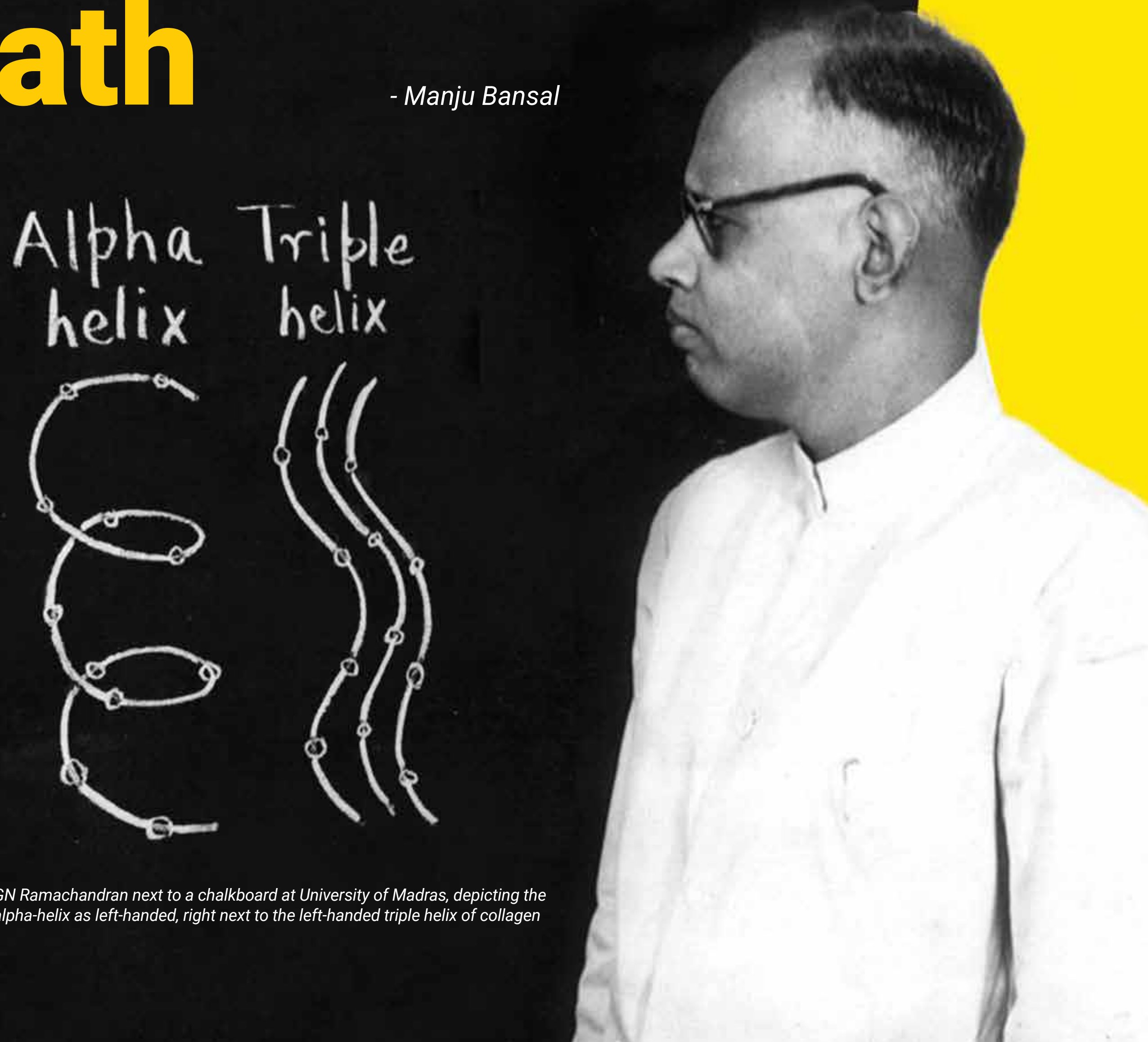


Photo courtesy: Manju Bansal

GN Ramachandran next to a chalkboard at University of Madras, depicting the alpha-helix as left-handed, right next to the left-handed triple helix of collagen

Manju Bansal, INSA Senior Scientist at the Molecular Biophysics Unit (MBU), joined the department in 1972 after completing her BSc and MSc from Osmania University, Hyderabad. She completed her PhD under GN Ramachandran, working with him on theoretical modelling of the triple helical structure of collagen. On the occasion of his birth centenary in 2022 – which also marks 50 years of her time at IISc – she describes what it was like to work with the renowned biophysicist and how it influenced her career.

When I was doing my Master's in Physics at Osmania University, biophysics was an unknown field. But in 1970, the Nobel Prize was given to three scientists [described as biophysicists] for their work on synaptic transmission in nerves. The news even made it to the local newspapers, and sparked my interest. We had heard that the University of Madras had a good biophysics department, but Prof R Srinivasan, who came from there to conduct our practical exams, advised me to apply to IISc for my PhD because Prof GN Ramachandran (GNR) had just moved here.

At that time, due to the Telangana agitations, our exams were routinely delayed. The day I got my interview call from IISc was the day that I had my last practical exam. When I asked them to postpone the interview, initially the authorities said no, but a few days later I received a telegram asking me to appear two days later. I finished my exam, and rushed over from Hyderabad to Bangalore – the first time I had travelled alone. At the lecture hall complex in IISc, where the Molecular Biophysics Unit (MBU) was housed, there was just one guy in the office and no other interviewees. He told me that the interviews were over, but as Prof GNR wanted to interview me, he had held back the interviewers who had come from Madras, for one more day.

That made me very nervous. The interview was held in Prof GNR's office, right next to his working table. He was very tall, and had an impressive personality. One of the first things he said was, "We don't want to find out what you don't know. We want to know what you know. You tell us the topics that you feel comfortable with." I rattled off a few topics, and the interview went on for one and a half hours. Apart from Prof GNR, there was Prof KRK Easwaran, another faculty member at MBU, and Prof C Ramakrishnan and Prof V Sasisekharan from the University of Madras [they later joined MBU]. After the interview, they told me that as long as I received a first class in my MSc exam, I could join the department. My results were only declared in August and I landed at IISc on 10 August 1972.

Modelling collagen using an IBM 360

There were five students in our batch, and we were the second batch in the department. Two of the students were already associated with faculty members who had come from Madras. Three of us were new. The other two were also assigned research areas and guides, but I was initially left high and dry, and just asked to do course work.

In September, Prof GNR returned from his trip abroad – he had an NIH fellowship at the University of Chicago and used to travel there every year – and I was told that I would be working with him. The other students scared me. One of them said, "You won't be able to work with Prof GNR; he's never had a girl student working with him because whoever joined left [before completion]." So, I was quite nervous when meeting him for the first time as my prospective PhD guide.

By then, I had gathered that one of his major contributions (described in two *Nature* articles in 1954 and 1955) was the triple helical coiled coil structure of collagen. There was a Visiting Professor from the USA (RS Bhatnagar) with whom he was planning to synthesise some modified tripeptides and study their effect on collagen structure. "We don't have much experimental data, but you can do the modelling," he told me.

At that time, we hadn't seen a computer, and I had zero programming skills. There was an IBM 360 in the Computer Centre which had less compute power than our cell phones now. Prof GNR had about 20 minutes of allotted time on the computer at midnight, and every working day, I would go to the computer centre at midnight to use those 20 minutes, which had to be shared with my senior, Ashok Kolaskar.

The problem I was given was this: In the collagen structure, there is an amino acid called hydroxyproline, a modified form of proline, which is rarely present in other proteins. Even in collagen, it is incorporated into the polypeptide chain first as proline, which is then hydroxylated by enzymes. Prof GNR told me that they knew from experimental data that hydroxyproline seems to stabilise the collagen structure. They had also guessed that it probably needs water molecules for stability. But if the proline is not hydroxylated, collagen doesn't form the triple helical structure; it disintegrates because the melting temperature is low. And they didn't know why this was happening.

I set about working on this problem. There were not too many papers for us to refer to. Luckily, IISc has always had a good library, so the old *Nature* papers that Prof GNR and others had published were available. But writing a program to generate the triple helical structure from the published tripeptide coordinates was tough. And Prof GNR wasn't a person into whose office you could just walk in and clarify doubts. Even though he didn't have them at the time, he subsequently installed red and green lights in front of his room. You were not supposed to enter if the red light was on. His secretary would call you and only then could you walk in. If we had some results to show, we had to go through his secretary to meet him. This experience influenced me to be a lot more approachable with my own students, and have an open door policy. Fortunately for me, Prof Ramakrishnan, who incidentally had worked with Prof GNR on the Ramachandran map, was a programming expert and very generous with his time, and helped me a lot in those early days.

I still think it was luck, but what I did find was that although hydroxyproline cannot form a direct inter-chain hydrogen bond, one of the water molecules linking two chains of the triple helix can, with some manipulation, form an additional hydrogen bond. The OH group of the hydroxyproline acts as an acceptor from the water molecule, and the hydrogen atom of the OH group juts out, and is thus able to form a hydrogen bond between one triple helix and a neighbouring triple helix. This led us to propose a possible role for hydroxyproline in stabilising the collagen structure.

I started the work in October and by next January, Prof GNR felt that it was time to write and send a manuscript for publication. This worried me since Prof

GN Ramachandran with students and faculty members at MBU including Manju Bansal (middle row) along with Dorothy Hodgkin during her visit to IISc in 1974. C Ramakrishnan is second from left and Sasisekharan second from right in the front row

GNR would sometimes throw away papers if even a comma or full stop was out of place. With MBU being located in the lecture hall complex, this would create a scene because everybody around would see it. When one walked into the mess after that, random students would say something like, “Who got it today?” I think one of the reasons I survived with Prof GNR was that my English was good.

We sent the paper out. Around that time, the Biochemical Society at IISc had arranged a two-day picnic to Ooty for which I had joined, and that was when the manuscript came back for some small revision. When I returned, he was a little upset that I was not there the day the paper had come back. I remember that in 1974 also, when my brother got married and my mother had back surgery, I had to take leave twice. His immediate reaction each time was negative. Then, the next day he would come and say, "Ok, go." So, working with him was a bit of a roller coaster ride. But I was fortunate to be able to publish a paper with him in just six months.

That paper, published in the journal *Biochimica et Biophysica Acta* in 1973, proposed a hypothesis on the role of hydroxyproline, and even though it was a theoretical paper, because he was the main author and it seemed to explain the experimental data well, it got cited quite a few times. Interestingly, 25 years later, when the crystal structure of a collagen-related oligopeptide was solved, the researchers found exactly the same kind of hydrogen bond formation we had theorised, and they were nice enough to acknowledge our contribution.

Photo courtesy: Manju Bansal

Graduating with a bit of drama

When I see my students now, most of them seem to need much more guidance, despite large amounts of information being available at the click of a button. But at that time, we had to somehow manage on our own, particularly since Prof GNR was away a lot of the time, and had fixed hours during the time he was here. We even joked that we did better work because of that.

Prof GNR didn’t teach a regular course but used to give special lectures twice a week spread over two or three months. He would give us tough assignments. In those days, there was no internet, no biophysics or structural biology textbooks, and journals arrived three months after publication by sea mail. You really had to apply your mind. Until recently, I was saving my assignments in which he had written “very good” or something similar.

Most people were scared of Prof GNR. He was very intense about his work. After having worked with Sir CV Raman, and due to his own exceptional intellectual abilities, he probably felt frustrated because none of us could reach anywhere near his level. Sometimes he was nice too, but you couldn’t predict how his mood would be. One day he might be angry with you, but the next day, although he couldn’t bring himself to apologise, he would somehow convey his feelings. The joke was that his wife probably scolded him about it. Recently, in a documentary that IISER Pune produced about his life, Prof GNR’s son spoke about how his father probably had bipolar disorder. It wasn’t a well understood disorder then, and we didn’t know he had it. But in hindsight, it explained a lot.

In 1976, by the time I submitted my thesis, I already had five or six papers published. He didn’t even put his name in two of them, saying that he was not here when I did the work. In that way, he was very honest and ethical.

However, there was a bit of drama before I graduated. When I gave him the final draft of my thesis, even though most of it had already been published, he said, “I don’t know; it doesn’t seem quite right. Why don’t you consult Prof Ramakrishnan?”

Now while Prof Ramakrishnan was extremely nice and helpful – I had published two papers with him – he was very slow, hence I felt that if I handed the draft to him for approval, it would considerably delay my thesis submission. So, I asked Prof GNR if he could just indicate what was wrong. He said, “I don’t know what is wrong, but I will know when it is right.” I was stunned by this reply.

Not knowing how to move forward, I went to meet Prof Sasisekharan, the Department Chair at that time, and explained that I did not know what corrections to make in my thesis write-up, but if Prof Ramakrishnan had to go through all my work, my graduation would be delayed by at least six months. The scholarship we used to get was Rs 250-300 per month and was only valid for four years. Since Prof Sasisekharan had also done his PhD with Prof GNR and knew him well from his Madras days, he advised me, “You just go to the hostel and don’t come to the department for two or three days. He will then call you.”

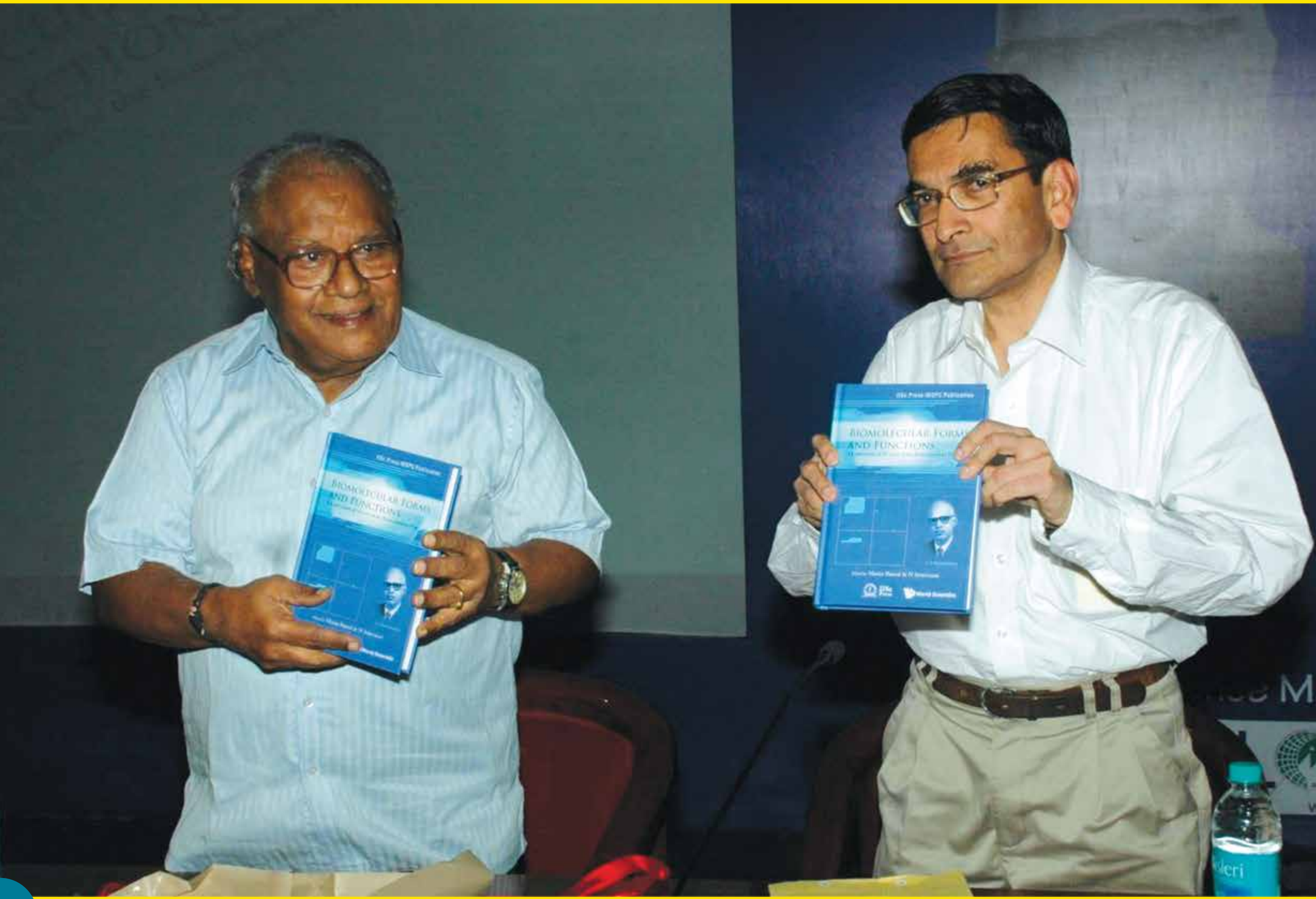
And that's exactly what happened. After a few days, his secretary rang up and said Prof GNR wanted to speak to me. When I met him, he said, "Give the draft write-up to me once again." The next day itself, he called me again and said, "It seems alright. I think you can submit it." While delighted at this sudden turnaround, until I got my reports, I was very tense about what the referees would have to say. Fortunately, everything went well. One of the pleasant memories I have from this time is when his wife – a wonderful woman although we had limited interactions with her – called me and congratulated me. She said, "I am so glad that my husband has at least one girl student who has completed her PhD with him."

Keeping in touch after PhD

Interestingly, after my graduation, Prof GNR and I had a very good relationship. He moved away from MBU in 1977-78, but later, when he was writing articles on mathematical philosophy, he would sometimes ask me to proofread them. A great compliment indeed! I also learned from others that whenever he gave lectures, he hyped up my work quite a bit and gave me a lot of credit. My husband, who also did his PhD at IISc, says that he heard Prof GNR speak once, and that he explained my work much better than I could. Even when I applied for a faculty position at MBU, he strongly recommended my case.

One of the things Prof GNR used to tell us was that in scientific research, we had to think differently, and take up problems that others were not pursuing, rather than doing "me too" type of research. He would also advise us not to accept everything that is published as gospel truth. He made us think and question dogmas. That has helped me a lot in my own career.

After studying proteins during my PhD, I switched to nucleic acids while working with Prof Sasisekharan,



CNR Rao and P Balaram releasing a book (edited by Manju Bansal and N Srinivasan) published to commemorate 50 years of the Ramachandran map in 2013 who was studying left-handed DNA – at that time, it was considered heresy to talk about anything other than Watson-Crick's right-handed double helical structure. I became interested in that, and continued in MBU for four years after my PhD. Subsequently I went to Germany on an Alexander von Humboldt fellowship for a year and worked on filamentous phage structures. On returning to MBU as a faculty member, my first student was a legacy from Prof GNR and worked on peptides, but simultaneously my group began exploring the sequence dependent variation as seen in oligonucleotide crystal structures, as against Watson-Crick's uniform double helix model for DNA. In 1988, there was a workshop at Cambridge on recent advances in nucleic acid structures, and Prof Sasisekharan, who was invited, decided at last minute not to attend. He suggested my name to the organisers, so I went, paying for the trip out of my own pocket (incidentally the air ticket cost me more than a month's salary), because there was no time to raise funds. But attending this meeting was extremely useful and led to me becoming a recognised member of the international community working on the variability of nucleic acid structures, and afterwards, our work on the sequence-dependent local geometry of nucleic acids and its biological implications has been widely accepted. I still give a lot of credit to Prof GNR for giving me the courage to explore new areas in my scientific research.

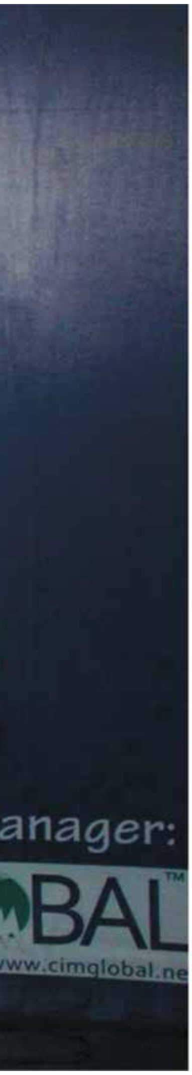


Photo courtesy: Manju Bansal

For his work on the Ramachandran map and on the collagen triple helical structure, Prof GNR was elected a Fellow of the Royal Society in 1977. However, he didn't get his due recognition in India; he was not even awarded a Padma Shri. It was indeed sad that he withdrew from active research when he was only 56 years old, when he could have contributed so much more. Maybe because of health issues, he didn't mentor any students after that, although he wrote some interesting monographs on mathematical philosophy.

In 2013, to commemorate 50 years of the publication of the Ramachandran map, we organised a major conference at MBU. About 700 people attended, including 40 scientists from abroad, even though we didn't pay travel assistance to anybody. Most participants felt that it was a long overdue recognition and tribute to Prof GNR's contributions to modern structural biology.

After retirement, he initially settled down in Malleswaram. When one of his sons returned from the USA to work at the Institute of Plasma Research in Gandhinagar, Gujarat, Prof GNR and his wife moved there. Then, after his wife passed away, and his son shifted to Chennai, he moved again. In January 2001, I happened to go to Chennai for a meeting at the University of Madras, in his parent department, and I asked one of the professors, Prof N Yathindra, to arrange a meeting with him. I knew that Prof GNR's health was not great and that he was living alone at an assisted elders' home. But when I met him, he was mentally still very alert.

At that time, I had done some work with my student on C-H…O hydrogen bonds which are not common. In fact, Prof GNR was one of the first people who had proposed C-H…O bonds for polyglycine-like structures. I realised that even though DNA was not his forte, this was something fundamental, and that he would like to know how C-H…O hydrogen bonds form in nucleic acids, especially at certain sequences where tracts of adenines and thymine nucleotides occur. He was very excited and immediately came out with one or two ideas for what we could do next.

That was the last time I saw him because, in April, he passed away. I was glad that I had at least gone and seen him just three months before he passed away.

Prof GNR appreciated good science. He moulded us into good scientists. In the long term, I feel that I benefitted immensely by just being associated with him. At a recent meeting that I attended of the Protein Data Bank advisory board, one of the co-panellists I met is a professor at Johns Hopkins University. Over breakfast, it came up that I had worked with Prof GNR for my doctoral thesis work. She became quite excited and exclaimed, "Oh, you are GNR's student? I present his work in my class all the time and never had the opportunity to meet him." And then she pulled out her mobile, took my photo and said that she would share it with her students to show that she had met the student who had worked with Prof GNR on collagen structure. I don't think I need to say anything more to highlight how much Prof GNR's work is appreciated by the scientific community and he is often considered as somebody who is better known than some of the contemporary Nobel laureates. I was indeed fortunate to have been mentored by a genius, at the nascent stage of my scientific journey.

As told to Ranjini Raghunath

Green

Photo: Midhun BS

A bulbul in the OoC courtyard

fingers

- *Samira Agnihotri*

Photos: Midhun BS

The bulbul family at their nest in the OoC courtyard

Most gardens on campus are looked after by the IISc Nursery, but some office staff have taken it upon themselves to add their own green touch

If you visit the Office of Communications (OoC) at IISc in the sultry months of April and May, you'll probably notice the bright and colourful flowers in the verdant courtyard. But you might miss the bulbul in her nest, ensconced in the Thunbergia vine. She comes from several generations of bulbuls that have raised their brood here since 2008, when Sampangi Ramu joined the Office as a helper (Multi-Tasking Staff or MTS). Since then, he has spent his free time turning the Office and its surroundings into a green haven. "There was space here, so I thought of developing a garden. I started small, by planting a few cuttings and was supported by the Chairpersons, and so have continued to maintain the garden till today," says Sampangi. Other than the fresh and clean air, he adds that the garden also provides a safe space for birds and other creatures to make their homes.

He attributes his love for plants to having grown up on campus. His father, Ashwath Narayan, worked as an attendant in the library, and he remembers having hundreds of pots at their home in the staff quarters. "Once, I had kept a pet rabbit, and one night, it ate up all the plants. We didn't keep any more plants after that," he rues.

His favourites are the flowering plants, especially roses and hibiscuses. "I want to add more flowers – I'm not satisfied yet," he confesses. He has also planted several fruit trees at the back of the Office – pomegranate, butter fruit, sweet lime and guava.

Photo: KG Haridasan

Sampangi Ramu and Gowtham S with a hibiscus plant that they tend to in the garden at OoC

Photo: KG Haridasan

Chikanna at work in the OoC garden

Like Sampangi, Kumar H also nurtures a passion for all things green. Also an MTS, he has been looking after the sizable gardens of the Department of Electrical Communication Engineering (ECE) for 23 years. His father too was an employee of IISc – in the Gardens and Nursery Section – and when he passed away, Kumar got this job. "I'm an all-rounder – I help with all sorts of jobs in the Department, but I am also in charge of the garden. I feel happy when I water the plants," says Kumar. He adds that he often talks to the plants and plays music when he is working on his own in the garden. His favourite is the Cypress tree; "the leaves are very fragrant," he explains. He has also planted different varieties of grass such as Bermuda grass, Mexican grass and Elephanta grass. "Students come and sleep on the soft and spongy Mexican grass, especially in the summer," says Kumar. Like Sampangi, he has also planted fruit trees – guava, badam, banana, papaya and chikoo. "There is also a jackfruit tree and mango trees. We distribute the fruits to everyone in the Department," he adds. Kumar's favourite spot is under the jackfruit tree. "ಸ್ವಲ್ಪ ರೆಸ್ಟ್ ಬೇಕಾದ್ರೆ, ಅಲ್ಲಿ ಹೋಗಿ ಕುಳ್ತುಕೊಂಡು ಬಿಡ್ತಿನಿ, ಮರದಡಿಯಲ್ಲಿ [It is slightly secluded and I like to sit there whenever I want to rest a bit]," he says.

A home garden away from home

For Deepak Shetty, a field assistant in Sumanta Bagchi's lab at the Centre for Ecological Sciences (CES), the motivation for tending to plants is different. His green space is a vegetable garden that spreads over a third-floor balcony of the B wing. "I live in a rented house and there isn't any place for plants there. Since I'm from the coastal belt of Karnataka, ಬಸಳೆ ಸೊಪ್ಪು [Basale soppu or Malabar spinach] is one of our staple foods. So, I grow it here," says Deepak. He also grows Mangalore cucumber, ginger, turmeric, two varieties of tulsi and ಪಲಾವ್ ಎಲೆ [Pulav leaf or Pandanus].

He has been with CES for 31 years, of which 24 were spent at the Sirsi field station. He feels that his long stint there instilled in him a fondness for plants. "I joined as a field assistant with Madhav Gadgil's group. No one else in my family has much knowledge about plants. Perhaps I was influenced by the ಕೈ ತೋಟಗಳು [kitchen gardens] which are common in the Sirsi-Malenadu region. We used to grow many vegetables there, and hardly ever bought any from the market," says Deepak.

Photo: KG Haridasan

Kumar H with his favourite plant – a Cypress tree

Photo: KG Haridasan

Deepak Shetty in his balcony kitchen garden

Large gardens like the ones at OoC and ECE need a lot of maintenance – regular watering, weeding, trimming, repotting, and so on. Sampangi is assisted by his colleagues Gowtham and Deepak whenever they are free, and another hired help, Chikanna, who comes every Sunday. Kumar is also assisted by Manjula, Lakshmamma, Devamma and Venkatamma, who join him in the garden every day from 4 pm to 5.30 pm, after finishing their housekeeping tasks in the Department. Both Sampangi and Kumar use compost made in-house from leaf litter for their plants and trees. The fallen leaves that are swept everyday are collected into a pit in the ground, and turn into compost in three to four years. The Institute established several such pits on campus in 2017.

"We have a lot of space, and many people have appreciated the garden at ECE. Visitors from abroad have taken photographs too. This is a great environment to work in, even though the salary is a bit low since I am a contractual employee," says Kumar. Sampangi, who has five years left to retire, shares this sentiment. "People who come from outside should feel happy when they come here [to the OoC]. That is my motivation — to create an environment where people feel: 'ಪರ್ವಾಗಿಲ್ಲ, ಐದು ನಿಮಿಷ ಕುಳಿತುಕೊಳ್ಳೋಣ' [Not bad, let us sit here for five minutes]."

Photo: KG Haridasan

L to R: Kumar H, Manjula, Lakshmamma and Devamma in the grassy lawns of ECE

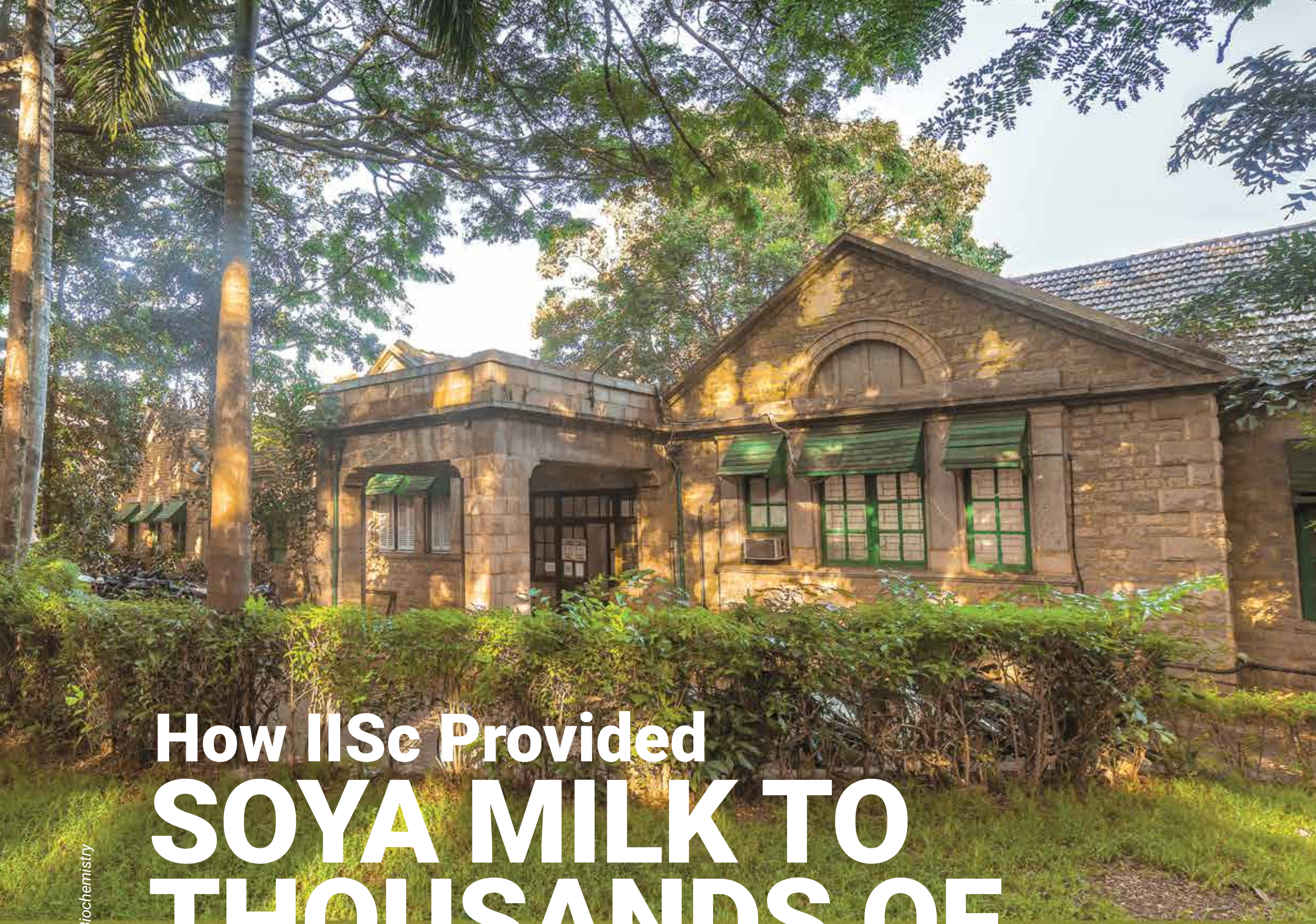


Photo courtesy: Department of Biochemistry

How IISc Provided SOYA MILK TO THOUSANDS OF SCHOOLCHILDREN

- Arun Chandrashekar

From 1945 to 1948, a programme at the Department of Biochemistry provided soya milk as a nutritional supplement

A pilot plant to produce soya milk was set up behind the department building

The Second World War ended with acute scarcity of food and milk in many parts of India. A year before the war ended, in September 1944, IISc created a new post for a Lecturer in Food Technology. It was filled by a scientist named Sasank S De, who had just transferred from the University College of Science at Calcutta (now Kolkata) where he had worked on different enzymes obtained from snake venom, from 1939 to 1944. He first became involved with soya in 1943 during the Bengal Famine, when he worked with BC Guha of Calcutta University to make soya milk for starving infants. Together with my grandfather, V Subrahmanyan, who was the head of the Department of Biochemistry at IISc, De worked on a unique programme that not only studied whether soya milk could supplement nutrition in children, but also involved feeding soya milk on a regular basis to thousands of children in Karnataka for around four years.

Towards the end of the war, India was not producing as much milk as it needed and malnutrition was a dire problem. It was thought that substitute milks could be made by blending proteins derived from different sources, particularly from oilseed residues including soya bean and groundnut. IISc's Annual Report of 1944-45 includes the following paragraph in a description of the work on soya milk: "Although several attempts have been made, in recent years, to popularise the use of soya-bean in India, much headway has not been made because of inadequate knowledge in regard to the uses of the bean. Soya-bean does not make a good *dhal* and if merely boiled and used, it has a low digestibility and its protein has a poor biological value. The high nutritive value of the bean, however, stands revealed when the bean is processed to yield a milk. This is a form in which soya-bean is mostly used in China, Japan, America and other countries."

In De and Subrahmanyan's recipe, initial soaking was carried out for two days in any suitable container to germinate the beans. If these beans were then dried, the skin was more easily removed. A modified coffee pulper (which was not efficient and required a lot of water) was used to remove the hulls. Kernels that had been dried were soaked again. The soaked kernels were placed in a steam-jacketed pan along with some water and the temperature was brought to 70 degree Celsius and maintained for 10 minutes. The kernels were then washed with water till the beans were almost white. A mechanical grinder, stone edge runner or granite triple roller mill was used to grind the beans to a paste. (An uncle of mine, S Sundaram, was one of three of Subrahmanyan's children that lived on the IISc campus. He remembers that the company Larsen & Toubro supplied some of the machinery involved, and that the whole process was carried out behind the old Biochemistry building at IISc.) The fine paste was then boiled with three times as much water containing sodium bicarbonate or glycerine to extract the bitter taste and give it a more appealing colour. Boiling was continued for 15-20 minutes after frothing reduced. The soya milk was filtered through woven cloth while hot. This prevented part of the cream from being lost. Salt and sugar were added, and the milk placed in a cold room prior to distribution. Calcium salts were added to the finished product. Milk could be further extracted from the residual paste using a wooden or metal press.

This soya milk was used in animal studies, and it was shown that in rat feeding trials, the soya milk supported growth almost at the same level as cow's milk. In later studies, De and Subrahmanyan found that the biological value (the amount of a protein absorbed by the body) of soya bean dal was only 55, while that of the milk was 80. However, soya milk had a digestibility of 92% while cow's milk had 88%. Soya milk carried with it enough B complex vitamins, and could ably supplement a rice diet.

In another paper written with a student named HSR Desikachar (who years later was my own guide), De investigated why the soya bean had poor nutritional properties. They discussed the role of inhibitors in soya beans as the reason for this. They found that the removal of trypsin inhibitors by acid extraction or any heat treatment, particularly wet heating or wet autoclaving, increased the nutritive value of soya. However, there was no change in trypsin inhibitor activity during germination, a process that vastly improved the nutritive and biological value of soyabean. In 1948, De, Subrahmanyan and Desikachar noted that only autoclaving soya milk at a pressure of 20 lbs or 25 lbs destroyed most of the trypsin inhibitor activity in lab studies.

Alongside their studies in the lab, they began human feeding trials as well. In an initial study, 129 children aged between a few months and six years were either fed cow's milk as a supplement or soya milk. Four-month-old infants did better on soya milk, while older children responded to both milks. Hospital feeding trials were initiated in collaboration with Dr Mary C Albuquerque at the Vani Vilas Hospital. The Indian Research Fund (later renamed the Indian Council of Medical Research), the Department of Food (later renamed the Ministry of Food and Agriculture) and the then Military and Civil Station of Bangalore funded a project in which IISc prepared soya milk and carried out animal experiments prior to a mid-day meal scheme for children. However, for the school feeding programme, the soya milk was not prepared using De's and Subrahmanyan's method of germinating soya, but with flour using a process developed by KP Basu based in Dhaka (now in Bangladesh), as it yielded more milk.

In a biographical note on Subrahmanyan for the Indian National Science Academy, CR Krishna Murti, a former student of his, writes: "For a long time, Professor Subrahmanyan was obsessed with the problem of the nutty flavour of the milk. It was found later that this could be overcome partially by fermenting the milk to curd." This tastier form of soya milk was mixed with rice and fed to the children in the programme.

In 1945-46, IISc produced 550 lbs of soya milk a day. The majority of it was converted to curd and mixed with rice for feeding 1,600 primary schoolchildren. Around this time, IISc developed a pilot plant for the manufacture of soya milk. At its peak in 1947-48, the Bangalore School Feeding programme saw 6,000 schoolchildren given curd prepared with over 600 lbs (around 272 kg) of soya milk.

Of the children in the school feeding programme, three hundred were divided into three groups of 100 each. Group A was fed with cooked rice and separated milk curd, Group B with rice and soyabean curd, and the control Group C received no extra supplemental

Image courtesy: CFTRI

Nutritive value of soya-bean milk protein

	Biological value	Digestibility co-efficient	Nutritive index	Protein efficiency gain in wt/gm. of protein intake
Cow's milk	82.8	89.7	74.3	1.95
Soya-bean milk	79.2	90.9	72.0	1.80
Raw Soya-bean	55.1	82.8	45.6	...

Image from "Milk Substitutes of Vegetable Origin", Indian Council of Medical Research Special Report Series No. 31, 1955

feeding. The weight and height gains were similar among children in groups A and B, while the values were lowest for the children in Group C. In addition to the school feeding programme, which ended in 1948, multiple experiments with soya milk were conducted between 1945 and 1948 with children in local orphanages and convents, according to the IISc Annual Reports.

De and team didn't just consider soya milk as being beneficial for children. They also suggested that soya milk could be used in tea and coffee, or to make curds and buttermilk. They suggested that soya was, on the one hand, a food supplement, and on the other, a milk extender. In 1950, IISc was even asked to conduct feeding trials in the army. Two hundred recruits were fed soya milk, and another two hundred were fed blended milk to evaluate the benefits of including soya milk in army rations. Preliminary results showed improvement in both groups.

Around the same time, IISc also conducted plant breeding research on soya under botanist and horticulturist BS Nirody. It imported 'Bansei', an American variety of the soya bean, from California "as a foundation seed for acclimatisation and selection for a more productive strain," according the Annual Report of 1949-50, which continued, "Results so far obtained are most encouraging and part of the acclimatised seed of the third generation was supplied on request to the Army Department at Dehra Dun and New Delhi under its Food Production Scheme. A fairly large successional crop is now in progress for further improvement in this direction." By 1952, the Annual Reports mentioned a new soya bean named Tata5, which was evolved at the Institute and supplied to researchers in China, the UK and Nyasaland (now known as Malawi).

However, the soya experiments and feeding programmes were not without logistical problems. The soya bean is native to East Asia, and at the time that De and Subrahmanyan were studying it, it wasn't widely available in Karnataka. Obtaining soya beans for a large-scale feeding programme from north India was difficult, and this was resolved through the intervention of Sir Philip Gaisford, the Resident in Mysore. The whole feeding programme was approved by WH Kirby, Rationing Adviser to the Government of India, and carried out with the aid of PM Jayarajan, an ICS officer who was the chief magistrate and collector of the Civil and Military station. Nevertheless, its limited availability was seen as a hurdle.

Another, and more significant hurdle, was the dismissal of research on the value of soya. In 1946, the Soya Bean Sub-Committee of the Nutrition Advisory Board concluded their 'Report on Soya Bean' saying they were "not in a position [...] to advocate *immediately* the encouragement of the production of soya-bean on a wide scale in India as a substitute for Indian pulses. The question should, however, be reconsidered if and when further evidence on the nutritive value of soya bean becomes available." In *Science and Culture* in 1946, De and Subrahmanyan wrote (perhaps partly in response): "Our attempts are based on the results of a very extensive series of scientific studies published in *Current Science, Science and Culture*, *annals of Applied Biochemistry and Medicine* and other journals. [...] Our findings are open to verification by any investigator who may be interested. To further demonstrate and apply our findings, we require the co-operation of the agriculturist to grow the bean; of the Government and the administrators for funds; of engineers in fabricating improved types of equipment, education and public health authorities for facilities and co-operation in conducting further trials, of medical colleagues for systematic observations, of the consuming public for sympathetic interest and helpful suggestions, and of fellow scientists for sympathy."

While soya bean investigations formed a major portion of the work done by De and team, they also did work on other nutritive foods. One area they worked on was rice gruel. They noticed that rice was often cooked with excess water on an open flame, and when the rice was drained, this nutrient rich water was wasted and thrown away. They appear to have sourced large quantities of this rice gruel (kanji) from the military, boiled it with roasted wheat flour and added sugar and soya paste (which was left over after the milk was pressed out of soya) to it. This mixture was cooled and set as a pudding with cardamom powder or vanilla essence for flavouring. The military would then deliver the kanji pudding to schools. The researchers suggested that big towns could produce kanji pudding using kanji from large feeding centres, and feed this to the poor and young schoolchildren as a public feeding programme. The researchers also observed that in homes, kanji could be mixed with cow or buffalo milk and set to a curd. "This would definitely be an advantage to homes which prepare their own curd and buttermilk and which could do with some extra supply," they wrote in March 1947.

Another vegetable-based milk the researchers considered at the time was groundnut milk. Good quality, mature groundnut kernels were mildly roasted to remove the testa or skin of the seed. The kernels were then ground to a fine paste in a roller mill or other suitable grinding machine. This paste was mixed with a quantity of water and filtered, and its pH adjusted to about 7.0. The milk was then deodorised with steam, cooled, fortified with minerals and vitamins, and homogenised. To the prepared milk, invert sugar was added, and the milk was seeded with buttermilk prepared from cow's milk curd. After 12 hours at room temperature (26-28 degree Celsius), the curd set to a thick mass. A feeding experiment, extending over a period of 6 months, was carried out on 42 girls aged between four and 11 years in a boarding home in Mysore to assess the value of adding a supplement of groundnut curd to the diet. Results of a statistical analysis showed significant improvement in the weight, height and nutritional status of children receiving the supplement of this curd over those in the control group (which received a pudding made of corn starch and cane sugar instead, to equalise the caloric intake in both groups). The authors expressed their thanks to the authorities of the Good Shepherd Convent in Mysore for providing facilities for conducting the experiment.

In 1950, Subrahmanyan left IISc to be the first Director of the Central Food Technological Research Institute in Mysore. His interest in vegetable milks was extended to the use of groundnut there. Milk from groundnut and soya bean fortified with minerals and the amino acid methionine as a substitute to milk was made there. Experiments were conducted on the nutritional status and general health of school children on diets supplemented with those vegetable milk and curds. Daily supplementation of 12 ounces of vegetable milk showed significant improvement in the growth and nutritional status of south Indian children, as revealed by the increase in their weights and heights, and higher retention of nitrogen, calcium and phosphorus. Research on soya and other vegetable milks continued in IISc under the Food Technology Section. However, De moved on in 1951, and eventually after he retired, he served as Senior Food and Agricultural Industries Officer for the Food and Agricultural Organisation (FAO) at the UN, based in Thailand.

In August 1955, research on milk substitutes supported by the ICMR was presented at a meeting of the Nutrition Advisory Committee held in Mysore. According to the report from the meeting, titled "Milk Substitutes of Vegetable Origin", vitamins, minerals and fats could be obtained from sources other than milk. The importance of lactose as a nutrient was questionable and any sugar could be used as a substitute. The report then compared the composition of whole and skim milk powder with that of almonds, cashew, coconut, groundnut and soya bean, and gave a detailed account of research on soya and groundnut milk. The report identified two key obstacles to the widespread use of milk substitutes: unfamiliarity and prejudice, and the fear that such products would lead to adulteration of animal milk. It ended by saying, "A favourable feature about the production of milk substitutes, especially in India, is the abundance of raw materials and the cheapness of the processed product which would bring it within reach of a large section of people who can ill-afford to buy them at the prevailing high prices."

Photo courtesy: Arun Chandrashekar

The author as a young boy in 1961 with his grandfather, V Subrahmanyan (second from right) and other food scientists. C Subramaniam, Minister for Food and Agriculture in the Madras government, is fourth from right

On a personal level, I find the soya milk investigations fascinating because they were so much more than just scientific experiments. They included trials on children in orphanages and welfare centres, which were overseen by the health authorities – but those norms were different from the ethics standards for trials using children today. Even so, the researchers were responding to an enormous challenge facing India, and were personally driven by their experiences of famine or of witnessing famine. I recall my guide, Desikachar, telling me that as a child experiencing famine in Chamarajanagar district of Karnataka, his mother would feed him sorghum, which was all that was available, but because she did not know how to cook it properly, he struggled to eat and swallow it. De had certainly seen the horrors of the Bengal famine in Kolkata, and Murti writes that in a 1945 lecture, Subrahmanyan spoke about seeing malnourished children and how "that vision had become permanently etched on his mind in his younger days and which in turn led him to take a vow to do something to relieve those distressing conditions."

I find it remarkable that at IISc, they even built a plant to manufacture large quantities of soya milk to feed thousands of children who were not part of the scientific experiments. It was a humanitarian project as well as a scientific one, and supplementing food for children remains a priority for most state governments – that's what makes the soya milk project such a special one.

Arun Chandrashekar has an MSc in Biochemistry from MSU Baroda and he obtained a PhD in Food Science from University of Mysore under the guidance of Dr HSR Desikachar. He worked at CFTRI in the areas of biochemistry, molecular biology and microbiology.

With input from Deepika S

To Patent or NOT TO PATENT?

- *Vibhu Vasudev*

Photo: KG Haridasan

IPTeL office alongside Pratt & Whitney R & D Center and the Centre for Battery Engineering

Patenting – getting legal rights over one's invention – continues to be a tedious process within Indian universities and there are many unanswered questions about the process. CONNECT sat down with Suryasarathi Bose, Associate Professor, Department of Materials Engineering and Chair of the Office of Intellectual Property and Technology Licensing (IPTeL), and office manager Vijay Singh to understand how patenting works at IISc.

The IP Cell was founded in 2004. What was the motivation behind its establishment?

Suryasarathi Bose: The primary objective of the IP Cell was to facilitate all the intellectual properties generated in the institute; to file them and to see if there are companies interested in licensing them. But the IP Cell has journeyed a long way and we are now the IPTeL because our objectives have widened. We also educate faculty members about properties they are sitting on that need to be filed, and about the fact that these technologies could be licensed to different companies. This process has generated a lot of interest among the faculty members because every technology they produce can be picked and protected and these technologies could be useful for the future as well.

We are also actively involved in the transfer of technologies to different companies. These companies are sometimes identified by the faculty members themselves. We have a great database of companies who regularly come in for different technologies. There are significant efforts invested in matchmaking between technologies and suitable companies. That is why the IP Cell became IPTeL because the objective also widened from going beyond the process of reviewing and filing [patents]. The process of searching for a suitable licensee has proved to be equally important.

Photo courtesy: Suryasarathi Bose

Suryasarathi Bose, Chair of IPTeL

Over the years, what have been the main challenges faced while evaluating, protecting, and licensing intellectual properties?

Suryasarathi Bose: If we look at the major institutes in the world, like the National University of Singapore for example, they have an intermediate lab which focuses on improving the level of the technology that a faculty member has developed to a much higher level before it gets considered for licensing. This is called the readiness level and industries look extensively at the 'technology-readiness level' before the technology can be taken over. These industries try to see if the respective technology is ready to go into the market or if it is still in the laboratory stage. If it's in the laboratory stage, many of these licensees would not want to take it up, or some of them offer to work closely with the faculty member to see if these technologies can be enhanced. We do not have such incubation labs to nurture the market readiness of the technologies that we wish to license.

If we have a similar model here at IISc with a research park where a set of engineers can take a particular technology and work on it to increase its readiness level, this can garner better results in terms of patenting more technologies over time.

The other challenge we see is that if we need to get these technologies to higher scale technology-readiness levels that are more durable and marketable, then we need substantial grants which we do not have right now. If the research path is being embedded in IPTeL, then another set of engineers and scientists needs to work on the process of identifying and engaging with licensees. We are not equipped with such funding or modelling in our institute yet. We have just begun having conversations, in the hope that we can implement such a model in our campus in the future. These models would certainly benefit us as they have already benefitted other institutions such as National University of Singapore.

How is the process of filing a foreign patent different from filing an Indian patent? What are the specific challenges involved?

Vijay Singh: Foreign patenting is expensive compared to filing patents in India. While filing for foreign IPs, there are two processes we mainly follow. One is to directly identify and file with the country we wish to get our IP patented from. The other way of filing is to do it via the Patent Cooperation Treaty (PCT). This process takes around 18 months to choose which country and company we can file our patents from, and upon identifying the licensing partner, things move forward.

Photo: KG Haridasan

IPTeL Manager Vijay Singh

Typically how long does it take to file a patent or licence a technology?

Suryasarathi Bose: It always differs on a case-by-case basis. Once a technology is discovered, say a new drug molecule by a faculty member, then we will go ahead and file a patent. But if the same drug molecule is to be licensed by a famous pharmaceutical company, then the company would like to see whether there have been some trials and successful models that the drug has been able to gather. This journey is going to be long if we consider the field of drugs or biology. But when it comes to the field of material sciences, this journey is shorter. We can show the properties of a new material and the company will independently verify these properties from a lab to certify the material before it gets taken into the market.

Hence, licensing operations remain vastly different. In some cases, coding alone would be licensed whereas in other cases it would only be the software. In such processes, the journey of licensing is even shorter. Materials and life sciences are the fields where we cannot really predict an accurate duration for the process.

How does IPTeL reach out and work with potential industry collaborators who are interested in commercialising and licensing IISc's patents or products?

Suryasarathi Bose: Most often, these technologies come out from joint or funded projects. When I say joint, it could be a project where the industry and the faculty member work towards the same technology. When it is an industry project and there is substantial intellectual input from the industry and the faculty member, these technologies tend to reach the market faster. Sometimes, the technology could have stemmed from a government-funded project. In such cases, where there are no industrial partners involved, then IPTeL's key role is to get a licensee on board. We already possess a database of industries interested in acquiring these technologies from us based on our prior experiences. We are expanding this database so that every time a new technology arrives, there is a certain ease in trying to map to a suitable licensee. This is one of the main initiatives undertaken by IPTeL.

A second initiative we have begun is engaging with firms whose primary goal is to take an IP and look for a licensee. There are firms with whom we have already started engaging; they try to make matches for the intellectual properties we provide and we try to negotiate the licensing terms and agreement with the potential licensee.

How does IPTeL support faculty members and researchers through the process of patenting and commercialisation?

Suryasarathi Bose: IPTeL has started helping faculty members and researchers in drafting their claims and we have firms that help us in these processes as well. The main efforts are towards trying to map and identify a potential licensee for the technology in question. We also work closely with the Government of India's Technology Development Board (TDB).

There are two technology incubators at IISc. One is at the Centre for Product Design and Manufacturing (CPDM) and the other one is at Centre for Nano Science and Engineering (CeNSE). They also have a large database of companies, and we try to regularly engage with them so that we are able to get wider publicity for the IP and succeed in patenting it with the right licensee. In this way, we support many faculty members and researchers who do not have licensees yet.

How does IPTeL increase awareness amongst students and researchers about IP rights and policies?

Suryasarathi Bose: We conduct IP awareness seminars. A couple of these seminars will take place in the near future. Our manager, Vijay Singh is instrumental in organising these IP awareness seminars. He educates and sensitises our postdocs, senior PhD students and faculty members about IP and why it is important to protect our IP before we make it available to the public.

There are successful models in top USA universities where these universities are run with the revenue generated from the licensing of their IPs. Our revenues are not that large yet, but through our seminars, we are trying to sensitise how initial revenue can be generated from the IP we are already sitting on. This information enables our postdocs and senior PhD students to see that their work may fetch revenue for the Institute during times when the funding from the government is becoming tighter and tighter. This path of generating revenue can become a sustainable and lucrative model for the institution as well.

What are some of the recent inventions that got patented through IPTeL?

Suryasarathi Bose: Two major inventions from the Institute that helped the country a lot recently during COVID-19 were the oxygen concentrator and the oxygen generation system. When the country was facing an oxygen cylinder shortage during the second wave of the pandemic, this technology aided hospitals and healthcare workers tremendously. These technologies were essential during those times and it is currently installed in many hospitals across Karnataka. But we did not garner much revenues from this technology as the goal at that point was to save lives. It was developed at IISc for societal benefit and immediately got pushed into the market without any thought about the rates of revenue that could be generated.

A company from North Karnataka recently approached us to take the oxygen concentrators and generators to remote areas as they aspire to establish an oxygen grid for the nation.

The Division of Mechanical Sciences has been the most active division in filing their IPs and getting them licensed. They have been successful in generating great revenue as well. Other divisions are also active but mechanical sciences occupies the top position.

Could you highlight some key examples of IISc patents or licensed technologies that have made a significant impact in their respective markets?

Vijay Singh: A majority of the IP that comes out of the Institute has a relatively lower technology-readiness level. It takes considerable time and effort for the companies to scale up these technology-readiness levels to go to the next stages of patenting and licensing processes.

Some IPs, like the one for obtaining silica from rice husk and a process for removing hydrogen sulfide from industrial wastes, developed by NKS Rajan, Principal Scientist at IISc's Department of Aerospace Engineering, did really well and are quite popular. Of course, IISc was the owner of this IP but recently we transferred it to Rajan's start-up, Mithra Increst. Satheesh C Raghavan, Professor at the Department of Biochemistry, had identified a small molecule inhibitor – SCR7 – as part of his work on cancer therapeutics. This invention gained significant attention from and got patented in both India and the USA.

Photo: KG Haridasan

IPTeL office staff from left: Chaitra, Bhavya Karanik, Shruthi M and Vijay Singh

What does a typical day in the office look like?

Suryasarathi Bose: We have a large office with five to six office staff and one IPTeL manager who tries to arrange these quick reviews for the IP applications that we receive. Based on the review process, we assign it to an attorney who works with the faculty member in understanding and trusting the claims associated with the process and in finally filing the claim.

We have an active WhatsApp group where we discuss the challenges daily, and once a week, we meet in-person to discuss the licensing types, the new IPs that are getting filed, the negotiations, licensing agreements and so on. We also have a think-tank that helps us to brainstorm possibilities and actions based on the challenges that we face.

The think-tank panel meets occasionally to see how we can expand the scope of IPTeL, how we can bring more revenue to the Institute through licensing and royalties, how to file more IPs that have societal relevance, and to discuss if we can change the current model in place to accommodate a better revenue-generating model.

Is digitising archival material really a no-brainer?

- *Deepika S*

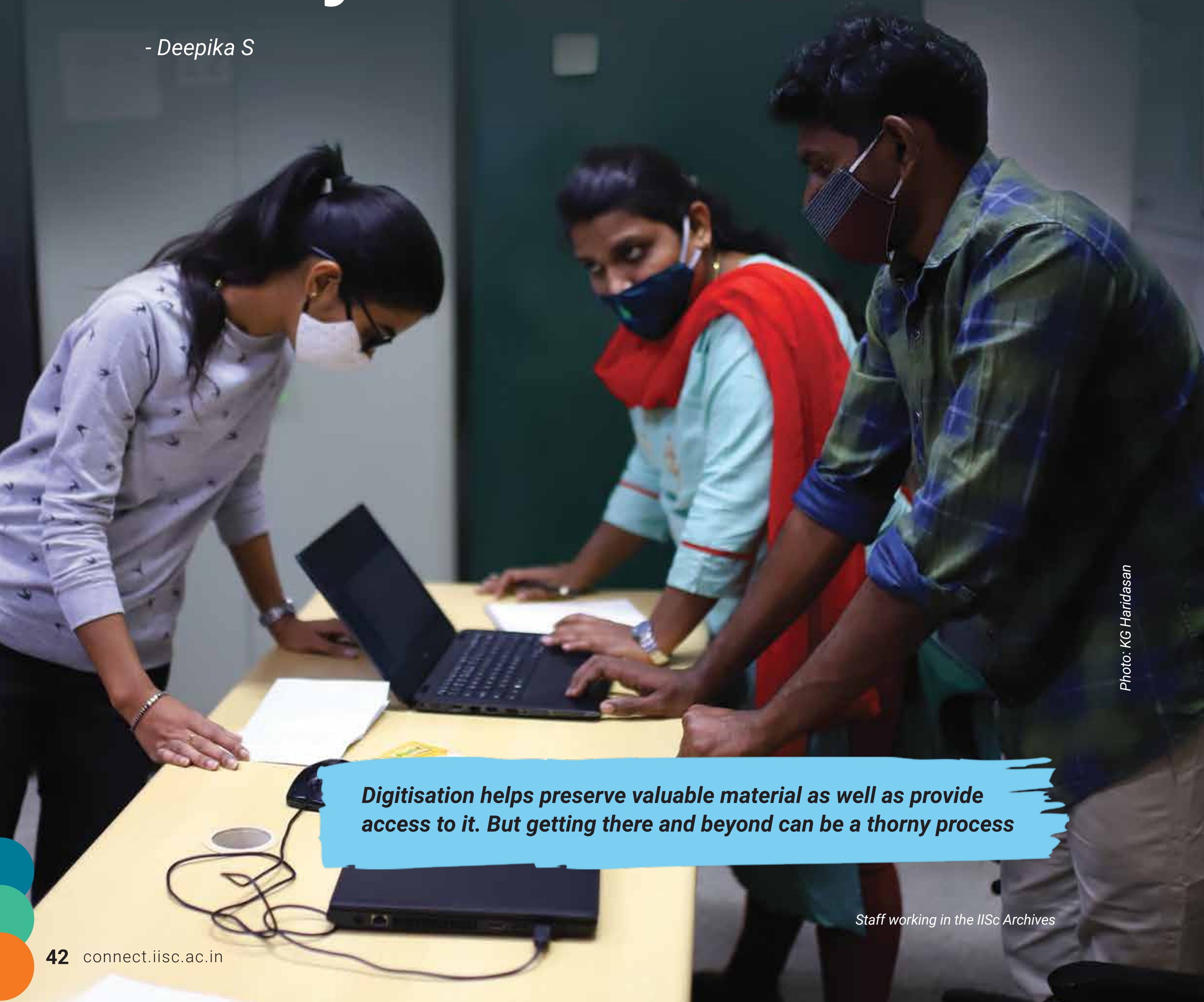


Photo: KG Haridasan

Digitisation helps preserve valuable material as well as provide access to it. But getting there and beyond can be a thorny process

Staff working in the IISc Archives

As staff in an archive, if there's one thing we learned from the COVID-19 pandemic, it is how important digitised material can be to researchers. With lockdowns and several travel restrictions in place after March 2020, the only way we at the IISc Archives could continue to respond to most requests from researchers was to digitise the documents they needed, if this was possible. We weren't the only ones: archives across the world found themselves fast-tracking work on creating or improving online access to their documents. Sounds simple enough, and seems like an obvious step for archives. But getting there can be a thorny process.

There are plenty of great reasons to digitise archival material, and perhaps the most important one is preservation. Physical material can be threatened by floods, fire, earthquakes and other disasters. And recent events like Russia's war with Ukraine have shown that institutions like archives and the material they hold can also be damaged or destroyed in times of civil unrest and international conflict. Making digital copies of archival material is a way of safeguarding its future, especially since these can be stored in multiple locations (like in cloud storage, where the server needn't be physically located in the same place as the archive).

Setting catastrophes aside, even in the daily functioning of an archive, users can be shown a digital copy, which means that the original won't need to be handled each time. If a document is already fragile and likely to deteriorate each time you have to pull it out and place it back in its container, having a digital copy can go a long way towards its preservation.

The other key reason why archives choose to digitise material is accessibility. Many archives see access as a core purpose, and put in enormous efforts to ensure that their valuable material is made available to people and organisations instead of being locked up in a vault. In one of its resources, the Tate Archive in the UK says that it embarked on digitisation and publication in conjunction with outreach activities to make sure that the collections were "not simply accessible, but accessed".

Though not all of our material at the IISc Archives is digitised, having digital copies of certain material that is likely to be requested often, such as Annual Reports or photographs of well-known scientists, has made it easier and quicker to share with users such as journalists or researchers. From an internal perspective, this has also allowed us to minimise the time spent responding to requests, and focus on other essential tasks such as building our catalogue. In an ideal scenario, the more we are able to digitise, the more time we may have to focus on other crucial tasks such as outreach, and processing new material.

A necessity

"For us, digitisation wasn't a choice, it was a necessity," says Shubha Chaudhuri, Director of the Archives and Research Centre for Ethnomusicology (ARCE) at the American Institute of Indian Studies in Delhi. As ARCE mainly holds audiovisual material, rather than paper documents, technological updates are a part of its fabric. In the 40 years that she has worked there, their main challenge has been hardware obsolescence: being able to retrieve recordings on open reels, audio and video cassettes, and other analogue formats depends on the availability of equipment to play them back. "Unfortunately, archives don't rule the market, and the equipment just stopped being made," she says. While they do preserve the original formats and try to purchase these players – sometimes old instruments that have been repaired and sold abroad on eBay – they still need to migrate to newer formats in order to continue accessing this material.

Photo: IISc Archives/KG Haridasan

Photo of Hans Krebs along with a handwritten note to the Biochemical Society at IISc, framed behind a glass pane

Maintaining a digital copy, Shubha points out, also helps to retain the audio and video quality. With analogue formats, there would be a 'master' version, and copies of it would by default be of poorer quality. There is also the problem of recordings deteriorating with playback (think of the fuzzy moments and warped sound that can come with a videocassette that's been played too many times). With digitisation, she says, "the first copy is as good as the tenth copy," and you can play a recording as many times as you like without it causing damage.

However, Shubha highlights the fact that digitisation is a continuous process rather than a one-time affair. "People in [audiovisual] archives learnt a lot about analogue, about its preservation and storage. The big advantage was that if you did it right – if you made your tapes right and you kept your storage facility well, your temperature and humidity was under control, you did your regular checks – you were good. You had your existing collections preserved and you could move on to new ones. And that's what we've lost with digitisation – there's no one-time solution. We have to replace our storage every three years as the hardware and technology become outdated so quickly." Financially, she says, this is difficult, as is keeping up with digitisation standards and technologies, which change frequently.

Resource intensive

Digitising archival material isn't quick or easy. Hundreds or thousands of fragile documents need to be scanned and each has to be carefully placed in a scanner manually. Overhead scanners may be required to take images from a height above the document (these are more effective for, say, large bound volumes that may not withstand repeated flattening in a typical flatbed scanner). Large items such as maps may require scanning or photographing in several installments (with the final image being stitched together). Photographing an image using an appropriate perspective, especially if the image is framed and behind a reflective glass pane, takes time and skill. Converting analogue sound recordings to digital ones can take at least as long as the length of the recording itself. Documents with text need to be made searchable using optical character recognition (OCR), and digital copies of archival material need to be checked to ensure they are of a high quality (a blurry scan of a document ends up being of use to no one). All of these require skilled personnel, time and funding – realistically, these are resources that many archives do not have.

Moreover, obtaining a digital copy is only half the task: ensuring that all digital material is properly structured, accompanied by metadata (including keywords that describe the material, which help users search for and locate it), and mapped to the original, is laborious but necessary. Roland Wittje, Associate Professor in History of Science and Technology at IIT Madras and Principal Investigator of its Archive project, says that without this processing, simply scanning all documents is like taking a bunch of museum objects and throwing them down a well in order to preserve them, and saying to users, "Just take them from there." He also cautions that it is easy to underestimate the amount of data that can be processed. Large government archives that he has seen in Europe, for instance, have "endless" data, he says. "To think that you can digitise it all [indicates a failure to] understand the amount of data there really is."

There's also the question of archiving material that is "born digital" – material that was created in the digital age, such as emails, or digital photographs. Archiving it is a challenge, Roland points out, as we create so much more digital material. Where earlier we might have thought twice about writing a letter, we now send so many more emails and messages on social media than is strictly necessary. "Anyone who has tried to archive their own email account knows what hell that is!" he says.

Whether digitised or born digital, managing this material still requires equipment for storage, scheduling periodic online backups, maintaining servers, adequate trained staff, and – though this may sound surprising – backups on tape or hard drives if necessary. Magnetic tape, which was once used for analogue storage in archives, appears to have evolved today into a practical tool for digital preservation. In 2018, Mark Lantz of the IBM Research–Zurich lab wrote in *IEEE Spectrum* that magnetic tape was still the future of data storage: though the speed of access was slower than a hard drive or semiconductor device, he argued that it didn't consume power (after the data was recorded), it was reliable, relatively secure against cyber attacks, cheaper, and could store more data than hard disks.

In 2020, IBM and Fujifilm teamed up to make a magnetic tape cartridge that could hold 580 terabytes (TB) of data, and was small enough to fit in the palm of one's hand. "Just to put that in perspective," IBM announced in a press release about the product, "580 TB is equivalent to 786,977 CDs stacked 944 meters high, which is taller than Burj Kalifa, the world's tallest building." But why would one need physical backup when cloud storage is available? Mark Lantz mentions an incident in 2011 when Google accidentally deleted saved emails in about 40,000 Gmail accounts, and was able to restore the data because it was backed up on magnetic tape.

Managing digital storage is a complicated enough task that some institutions outsource it, just as some archives hire private vendors to do the job of digitising. For example, the Endangered Languages Archive (ELAR) in Berlin, Germany, which has material from around 600 languages (including 30 from India), is a digital archive based on a commercial system called Preservica to ensure a reliable digital repository solution, including workflows for format conversion, migration and backups.

Ethical questions

Apart from the logistical challenges that digitisation poses, there are several ethical questions that accompany blanket policies to digitise material. Shubha, whose fieldwork as a researcher has involved interacting with performers and community folk artists,

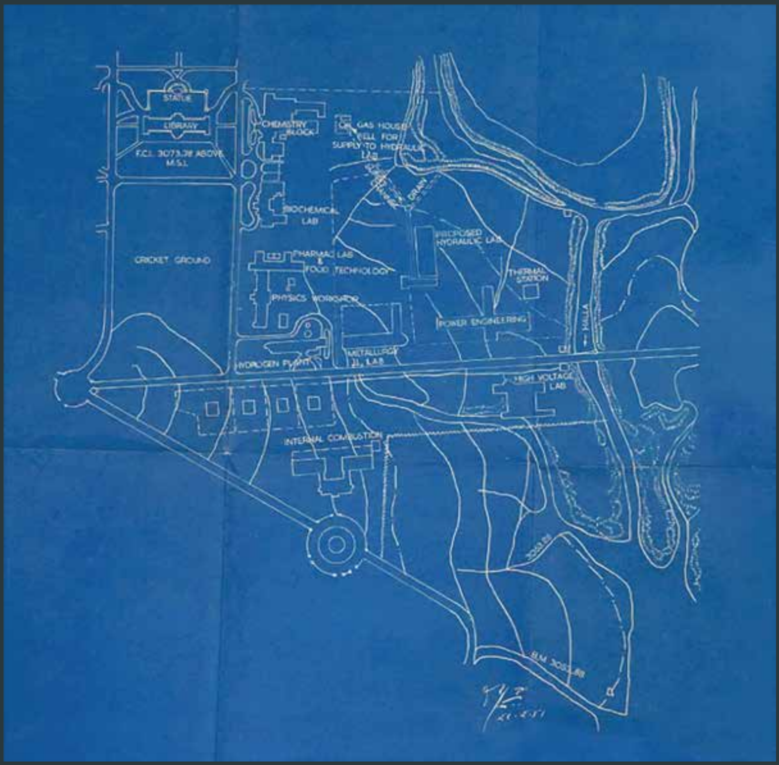


Photo: IISc Archives/KG Haridasan

Digitised map of the IISc campus from 1951

says that because digital copies of recordings are easily shared, they are also easily downloaded and distributed or monetised without permission, which violates the intellectual property rights of performers. She also talks about scenarios she's encountered in which users don't always honour agreements to use digital material solely for their stated purpose, or don't always reuse material in a way that is respectful to communities and individuals (she recalls a user offering to connect ARCE to a nightclub in London to sell their footage of a "possessed" woman in a village in Rajasthan). Unauthorised sharing of material can break a donor's trust in the archive, Shubha says, as putting digital material online is akin to publishing – something the donor didn't necessarily sign up for when depositing material in an archive. Farah Yameen, an independent researcher, archivist and oral historian, points out that digitisation and public access is often a condition of funding – an aspect that complicates an archive's decision to digitise or not digitise.

Aside from issues of copyright, when material is digitised selectively, there is also the question of where the resources should be invested – and what suffers in the bargain. Roland says, "During COVID-19, we learned that everything that is accessible online will be used more. Historians need to think very carefully about why they are doing that – they are creating new kinds of hierarchies while upholding old ones." He points out that a science archive would be more likely to make the papers of someone famous like Charles Darwin, or a Nobel laureate, accessible online. Historians tend to focus only on this material and end up making well-known scientists even more prominent in their writing, while ignoring those who may not have material about them available online. "It's as though if something doesn't exist on the internet, it doesn't exist at all. [For an archive] it's an ethical question: which repositories do you make available and which ones do you not?"

"People are right when they say we cannot avoid the digital," says Roland, but he is skeptical of the efficacy of efforts to manage material after it has been digitised: "I am just saying that so far we haven't been very good at it." And ultimately, he says, we still need the original physical documents to refer to: "It's not just about scanning – there are a lot of layers on the document." In a blog post about why archives don't digitise all of their material, Samantha Thompson, archivist at Canada's Region of Peel Archives, writes that digital copies don't completely capture physical characteristics (like thickness and type of paper, or marks of wear, which convey illuminating information) or context (like sticky notes, which may contain information relevant to the document on which they are stuck, but also obscure a portion of the document). "The digital copy is not a true copy, right? The only true copy of the original is the original," Roland says with a laugh.

Even so, many archives still push forward with digitisation plans and workflows, and at the IISc Archives, we hope to do so too. Perhaps the most time and effort that we put into digitising a single document so far was in 2021 when the Department of Mechanical Engineering requested a copy of a map of IISc's campus from 1951, to be used in a publication commemorating the department's 75th anniversary. The map was too big for the scanners we had at the time and was creased across its length and breadth because of the way it had originally been stored. After some attempts (with limited results) to flatten the document as best we could, we spread it on the floor over sheets of acid-free paper and weighed down the edges while photographer KG Haridasan stood above it, perched precariously with one foot on a table and another on a chair, so that the photograph could be taken from a height and under suitable lighting. We did our best in response to an urgent request, but we hope to have the opportunity for a do-over in the future. It's worth the effort: archives are meant to last across the ages, and if our physical material doesn't survive, at least we'll have the next best thing in line.

'I loved working at the library'

- Kavitha Harish

Photo courtesy: Mythra Gangadharaiah

Mythra Gangadharaiah joined IISc in 1969 and worked at the Institute until she took voluntary retirement in 2003. She initially worked in Unit III, the postal section in charge of sending and receiving the Institute's correspondence with the outside world. After two years, she was posted to the office of the JRD Tata Memorial Library, where she spent the rest of her career. Mythra spoke to CONNECT about her life at the Institute and the experiences she has had during the 34 years of her service.

Mythra Gangadharaiah in the JRD Tata Memorial Library office

Can you tell us about your early life and education?

I was born in my mother's native place – Banavara, Arasikere Taluk, Hassan District – and completed my school and college in Bangalore where my father was employed.

Although my father wanted to stop my education after SSLC, my school teacher met with my parents and urged them to send me to college as I was good at all the subjects. In those days, girls from orthodox and traditional families were scared of stepping out of the house for either studies or a job, as it would lead to unnecessary remarks from outsiders. I swore to my mother not to commit any mistakes that would bring embarrassment to my family. After this, my father permitted me to study Home Science from the VHD Central Institute of Home Science.

Since I had studied in the Kannada medium in higher secondary school, I found it a little difficult to follow the subjects in English in college. I had to read all the books from secondary school in English. I completed my BSc degree in 1968 and simultaneously joined a typing and shorthand course after completing the respective exams. Later, in 1987, I also pursued an LLB degree while working at the Institute from Sri Renukacharya Law College, Bangalore.

How did you come to know about IISc? What made you join IISc and when did you join?

As soon as I completed my degree along with shorthand and typing in 1968, I registered my name at the Employment Exchange and immediately started getting calls for interviews from many departments. I also got an appointment order from BEL (Bharat Electronics Limited). One of my father's friends was working at IISc. He got me an application form for the Lower Division Clerk and Stenographer position. I applied for it and attended the interview. My father advised me to join IISc since it is an educational institution and not a factory like BEL.

I was eager to join IISc, but I initially didn't get any response to my application. I waited for three months, and then one day, I decided to meet the Registrar of the Institute to enquire about my appointment. Mr GD David, Personal Assistant to the Registrar, was kind enough to permit me to meet the Registrar, Mr SS Prabhu.

The Registrar asked me why I needed the job. I informed him that I wanted to help my family and support my brother's education, as he had to stop his studies and take up a job due to financial constraints. I felt that I needed to support my father financially. After hearing me out patiently, the Registrar issued an appointment order, and I reported to the Assistant Registrar of Unit III as a Lower Division Clerk (LDC) on 3 September 1969.

How many departments have you worked at? What was the nature of your work in the Institute?

I worked in only two departments at the Institute – Unit III for the first two years, and the rest of my career was spent in the JRD Tata Memorial Library. Both were in the Main Building. In Unit III, I was assigned the job of dispatching letters received from all units and departments of the Institute. It was a good opportunity to learn about all the correspondence being sent from and received at the Institute. All my colleagues in Unit III were very friendly. After two years, I was transferred to the JRD Tata Memorial Library as a Stenographer Grade II and I reported to Prof ES Rajagopal, the Librarian in-charge in 1972. I still remember how he welcomed me with a nice smile. I worked in the library for 31 years till I retired as a Personal Assistant in 2003. I have worked with Mr TKS Iyengar, Mr Malwad, and many professors who were temporarily in-charge of the library.

Since you have spent most of your career at the library, can you tell us about the changes that you see now as compared to the earlier days?

The Institute's library is (and was) one of the biggest and best libraries in the country. Started in 1911, as one of the first three departments in the Institute, it has become a national resource centre in science and technology. The library completed its centenary year of establishment in 2011. Initially, it was housed in the Main Building; it moved into its present premises in January 1965. In 1995, the library was renamed as the JRD Tata Memorial Library (JRDTML).

When I was working at the library, the number of permanent staff members was nearly 70 including the librarian, three deputy librarians, assistant librarians, copy machine operators, binders, helpers and the editor of the *Journal of the Indian Institute of Science*.

As a stenographer, I was also a personal assistant to the Librarian and assisted him in all the administrative work, organising daily schedules and appointments, arranging meetings, answering and routing phone calls, taking messages, preparing meeting agendas and minutes, and so on. If there was any request for books from the Director or Divisional heads, I would issue those books. I also processed the approvals for library reference requests that we received from all over the country. Readers from many universities, colleges and companies used to come to the library for reference work, so my job also involved helping them find the reference material they needed. The work at the library was challenging, and I loved the job.

What were some of your memorable experiences at the Institute? Did you get the chance to meet with any famous personalities?

Some of the unforgettable experiences were attending a conference on science and spirituality, participating in the Gandhi Jayanthi celebrations, and participating in cultural activities organised by the Ladies Club at the Institute. I had the privilege of meeting Dr Raja Ramanna, Prof Satish Dhawan, Prof Ramaseshan, Mr JRD Tata, Prince Charles, and Mr Ratan Tata. I got to see them up close at the Institute.

Other than work, were there any other activities that you participated in?

Twenty five years ago, a few colleagues and I formed a Ladies Club, which is now called the Women's Forum. This was made possible with support extended by Ms Uma Chandran, Assistant Registrar and Dr Thilagam, Hindi Officer. Gradually we were able to expand the club and organise many activities. These included lectures from eminent artists, celebrations on International Women's Day, various classes on Saturdays and during the lunch hours, and so on. We would have lunch quickly and run to attend classes in singing, drama and so on, and we enjoyed practising and performing at various events on campus. These events brought together most of the women staff members on campus.

How has the Institute changed since the time you joined?

When I joined the Institute, it had only a few women staff members. Now I see that the majority of the supporting staff members are women.

I have personally seen Prof Dhawan, Prof Ramaseshan and many others coming to the library to look up some references. Now, we hardly see readers in the reference area, and the number of staff members has also reduced considerably due to digitisation.

Photo courtesy: Mythra Gangadharaiah

Mythra singing the invocation during an event organised by the IISc Employees Association. Seated from left to right: Nalini Dhawan, Satish Dhawan, S Ramaseshan, CNR Rao, Nanjunda Rao and Ramu

Can you tell us about your family?

I was born in a lower middle-class family with strong values. I have four brothers, and all of them are well settled. Although my mother didn't have much education, she had a wonderful memory and was very business-like. She struggled hard to bring us up and educate us. In the 1960s, there was no gas or electricity for cooking. She used to cook using charcoal or firewood. Her health deteriorated because she was asthmatic, and this spurred me to start cooking at the age of eight. We could eventually get her proper medical treatment. My father was a simple and spiritual man. He first worked at Binny Mills and later joined Hindustan Machine Tools (HMT). He was also a devoted Rashtriya Swayamsevak Sangh (RSS) worker.

In 1972, I got married to Mr Gangadharaiah G who was working in All India Radio. He was a resident of Yeshwanthpur, and while riding the cycle to his office at Raj Bhavan Road, he used to pass by the Institute and look at it with admiration. After our marriage, he told me that he felt overwhelmed to marry a woman working at the Institute. He then got a job at the National Aerospace Laboratories (NAL), Bangalore, as a Senior Technical Assistant in 1975 and retired as a Technical Officer Grade III in 2001.

I have two daughters who are well settled. They studied at the Kendriya Vidyalaya school in IISc since I was working here. My first daughter, Dr Manjula Meda, is working as a Consultant, Clinical Microbiologist, and Infection Control Doctor at Surrey Hospital in the UK. My second daughter, Dr Divya G Nallur, is a Clinical Director and Senior Consultant Psychiatrist at Amaha Health. I am now retired and living comfortably in Tatanagar, Bangalore, in a residential layout created by the Institute staff.

How are you spending your retired life?

I learned to play the veena, and I love to sing, especially devotional songs. Ms Dharma, the wife of Prof V Rajaraman, is my teacher. She is a perfectionist, and I am lucky to learn from her.

During the COVID-19 lockdown, I attended many online classes on meditation and yoga, which keep me healthy and happy as I grow older. I also served one term as an elected committee member of the Residents Welfare Association at Tatanagar. I interact with my colleagues online and offline, and also visit a nearby home for the elderly with my friends to help.

With wonderful weather and lots of greenery, I have never felt the heat of summer at any time while on campus. IISc has provided me with all that I dreamed about in life. It has been a great honour to serve at the Institute.

Kavitha Harish is Personal Assistant to the Assistant Registrar (HR, Council)

Pradipta Behera, IISc Nature Club