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# FITT FORUM

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## Clean India, Developed India

The reality is that backwardness, poverty, poor education, exploitation, joblessness, pollution, sanitation and other social and cultural challenges have kept us tied in knots for far too long. The very few examples that get reported only alludes to the scale of challenges before the nation. Most of the issues hardly get noticed. The media picks up only a few which then get highlighted. The fact is that the nation faces a multitude of issues that need to be addressed and cannot be brushed under the carpet. True development cannot happen without inclusion in the development process. The current national themes like Make in India, Digital India, Clean India are indeed laudable. Make in India ought to be seen beyond manufacturing by focussing on the entire value chain from conceptual design onwards. The digital footprint across the country can help us leapfrog the development journey. But, it is the Clean India campaign that should merit special attention as this is one critical area that can dramatically alter the country's landscape. Even if we achieve a fourth of our targets, we would have achieved a lot. The challenge is greater because this is linked with behaviour. It is easy to start with public places, institutions etc. and adopt practices such as at Delhi Metro. This should be the priority and hopefully rest will follow. In this regard, sustained publicity campaign has to be imaginative lest we stumble. Accomplishments on the cleanliness front would have the ripple effect towards reducing disease and pollution, increasing tourism and productivity and reducing costs towards sanitation and river cleaning etc. Who does not like to get away from the filth? The role of an individual and the family in the campaign has to be emphasized. There could be attractive awards/rewards in the domain of cleanliness. While technology and business innovations can be of tactical advantage, it is the sensitization of the new generation from school kids onwards that can ensure durable outcomes. Clean India has to be linked to the development campaign. Any criticism/cynicism that it may invite has to be totally ignored. People like and support good and smart ideas!

*Dr Anil Wali*

## Content



Launch of the Pfizer-IIT Delhi Innovation and IP program

Mark Zuckerberg during his Townhall Q&A session at IITD

## Tech Tales

# Cerebral Haemodynamics and Role of Perfusion Imaging in Stroke

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### Cerebrovascular Disease and Stroke

Stroke is a sudden loss of neurologic function resulting from decrease in blood flow to brain because of either block in the supplying blood vessels (called ischemia) or traumatic leak of blood from vessels (called hemorrhage). Depending on the duration of this cerebrovascular disturbance, stroke can cause permanent neurologic damage, disability, or death. Stroke is the third leading cause of death, with only heart disease and cancer accounting for more mortality[1]. Ischemic stroke accounts for 87% of all strokes [1].Among persons aged 45 to 64 years, 8% to 12% of ischemic strokes result in death within 30 days[1]. Stroke is also the leading cause of neurological disability worldwide. It accounts for more than 4% of direct health-care expenditure, with an absolute cost of over US$40 billion and also has substantial indirect costs related to complications, such as post-stroke dementia, depression, falls, fractures and epilepsy. However, over the last decade significant progress is being made in the prevention and treatment of stroke. Two reports in 2011 showed that stroke mortality has fallen significantly over the last decade, [2,3] probably due mainly to more effective prevention and improved treatment[4].

### Patho-Physiology of Stroke

Survival and normal functioning of brain is dependent on an adequate supply of oxygen and nutrients via blood, while any compromise in cerebral perfusion can result in neuronal cell death, which is classified as neurological stroke. Measurements of perfusion are of direct diagnostic value in vascular disorders, but they also serves as biomarkers for a broader range of physiological and pathological functions. A close coupling between cerebral blood flow rate and metabolism allows regional brain function to be assessed through measurements of cerebral perfusion. A reduction in cerebral perfusion leads to ischemia which is a recoverable state if normal blood supply is restored. However, a massive compromise or complete occlusion of cerebral vessels causes irreversible neuronal death called necrosis or infarction which will initiate a self-destructive mechanism of apoptosis. Within the ischemic cerebrovascular bed there are two zones of injury: the core ischemic zone (infarction) and the "ischemic penumbra" (an ischemic zone which still contains viable cerebral tissue) [5]. Figure 1 showing the schematic diagram with dead infarcted tissue in the core of ischemic zone surrounded by penumbra under haemodynamic stress.

In the core ischemic zone, if blood flow is below 10% to 25% of normal levels [6], the loss of adequate oxygen and glucose results in rapid depletion of energy stores. Severe ischemia results in tissue necrosis which slowly expands; this is called the area of infarction. However, brain cells within the penumbra, a rim of mild ischemic tissue lying between normal tissue and the area of infarction, may remain viable for several hours. The penumbral zone (25% to 50% of normal CBF) [6] attempts to maintain the tissue metabolism by altering its capillary haemodynamics or by recruiting blood supply through collateral vessels. The penumbra tissue is clinically referred to as the "tissue at risk" since the altered haemodynamics or collateral supply is not always adequate in maintaining the neuronal demand. If reperfusion is not established within a few hours (called the "window of opportunity") the cells in penumbra zone will die. The penumbra is where quick medical interventions are most likely to be effective and hence is the zone of high clinical interest.

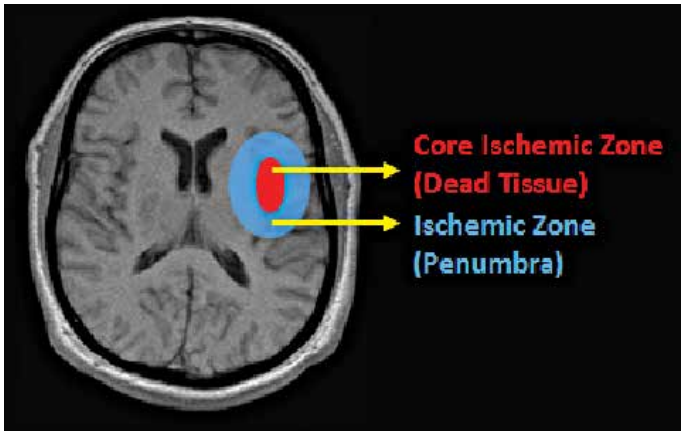


**Figure 1:** Showing the core Ischemic zone (dead tissue) and the surrounding ischemic penumbra.

### Role in Imaging in Stroke Diagnosis

Medical Imaging plays a vital role in diagnosis and prognostic monitoring of patients with stroke. Computed Tomography (CT) imaging is widely available in India. CT is an x-ray based imaging modality that quantify the attenuation of x-ray beam by the body tissue to reconstruct a tissue image. CT can help in disease diagnosis but unable to predict the amount of salvageable brain tissue (penumbra) which is a key factor in deciding the treatment.

Magnetic Resonance Imaging (MRI) is another imaging modality that relies on the magnetic resonance properties of the protons in body under the influence of an externally applied magnetic field. The variations in the resonance property of protons is used to reconstruct the image of the body. Diffusion MRI is an imaging protocol that is able to determine only the coredead region of brain. Another special type of MRI protocol, called dynamic susceptibility contrast MRI is the one commonly used in estimation of blood perfusion in brain for diagnosis of stroke; thus is also commonly called Perfusion MRI. Perfusion MRI can help to determine the area of brain that is completely dead and regions that are under ischemic stress (penumbra) where active intervention might be most successful. Perfusion MRI relies on the injection of a bolus of a paramagnetic contrast agent (mostly Gadolinium chelates) into blood stream, which produces a transient decrease in MR signal intensity on a series of MR images acquired during its passage through the brain [7]. The regional changes in the signal intensity of the brain has the information on blood perfusion to the brain.

## Mathematical Modeling and Quantification of Cerebral Perfusion using MRI

The change in the perfusion MRI signal induced by paramagnetic contrast agent is proportional to the amount of blood flow and is also affected by how the study is performed; i.e. the contrast injection volume and injection rate. Using indicator dilution theory [7], the time course of tissue signal can be expressed as a convolution of the bolus injection function, called input function and tissue haemodynamic function called the residue function.

So far most of the clinical studies use blood flow rate as the key marker for diagnosis of stroke and identification of penumbra. Our research group expertise in deconvolution methods. Perfusion analysis is an ill-posed inverse problem. Various model based analysis methodologies has been implemented in the past, using strong assumptions for the underlying cerebral haemodynamics [8]. Non-parametric analysis methods are more widely accepted by the community but these are sensitive to noise especially in case of ill-posed problem [8]. We have designed a Bayesian based non-parametric deconvolution methodology called Control Point Interpolation (CPI) method [9]. CPI method works with a combination of Bayesian priors and smooth spline interpolation technique to assure a physiologically plausible haemodynamic response function [9]. We are interested in evaluating changes in the shape of the haemodynamic function as a marker of disease progression because shape of the residue function encapsulates the underlying variations in capillary haemoodynamic. Figure 2 showing the diffusion, perfusion MRI and the variations in cerebral haemodynamic function in normal, penumbra and core infarcted tissue for a patient with chronic ischemia.

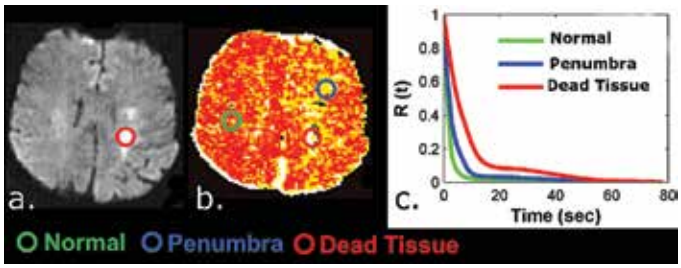


**Figure 2:** (a) Diffusion MRI showing dead brain region, (b) Perfusion MRI showing areas with poor perfusion both dead tissue and penumbra, (c) Haemodynamic variations from three regions showing changes in shape of residue functions.

## Future of Perfusion imaging

Perfusion imaging is one of the highly researched areas in MRI community. It is an interdisciplinary area of research requiring close collaboration of both medical and engineering community. Other than application in neurological stroke, perfusion imaging is also used in assessment of cancer diagnostics and grading of cancer as a marker of disease progression. Our research group is working closely with All India Institute of Medical Sciences, New Delhi on designing novel quantitative analysis methodologies for stroke and cancer imaging.

One of the limitations of the perfusion MRI is the use of exogenous contrast agent as injection, mostly Gadolinium chelates. Another perfusion imaging modality has thus captured the attention of MRI community, called Arterial Spin Labelling (ASL) MRI. In ASL arterial blood water is used as an endogenous contrast for perfusion imaging in conjunction with MRI by magnetically labeling of water in blood proximal to the tissue of interest [10]. The tissue of interest is first imaged without labeling followed by labeling of the inflowing blood and imaging the tissue of interest again. The subtraction of the two images gives a measure of tissue perfusion. As compared to DSC-MRI, ASL has poor SNR for perfusion quantification but the benefit is that it does not require the administration of exogenous contrast, which is contraindicated in renal insufficiency and ASL also provides a direct quantification of absolute CBF. The utility of ASL in characterizing perfusion in both acute stroke [11] and chronic cerebrovascular disease [12] has already been demonstrated and is currently in the state of further clinical validation.

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# Waste Management in India – Perspectives and Challenges

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## Urbanisation and India's Waste Management Challenge

India generates about 60 million tonnes of trash every year. Ten million tonnes of garbage is generated in just the metropolitan cities: Delhi, Mumbai, Chennai, Hyderabad, Bangalore and Kolkata. Delhi generates approximately 9,000 metric tonnes of solid waste, which is dumped into four landfill sites. In addition, Delhi's four landfill sites extend over 164 acres, when the current requirement is nearly four times the available area – 650 acres, according to a 2011 report by the Central Pollution Control Board. Mumbai generates 6,500 metric tonnes of garbage daily, including 2,500 metric tonnes of silt and debris, besides 25 tonnes of bio-medical waste. A significant amount of the waste (4,500 metric tonnes per day) is dumped at the eastern suburb Deonar dumping ground which will expire by the end of 2016. Other landfills in Mumbai have shut down due to over-use. In addition, Mumbai also generates 21 lakh tonnes of industrial waste per year, which is half of the national total, according to the Central Pollution Control Board report. Industrial waste is also dumped into the landfills. The landfills of most of these cities are already overflowing, with no space to accommodate fresh garbage waste. According to an expert at the Centre of Science and Environment, instead of constructing new landfill sites, the government should be looking into innovative methods to dispose and recycle its waste. The reason why most landfill sites are over-flowing is because the current waste disposal system is flawed.

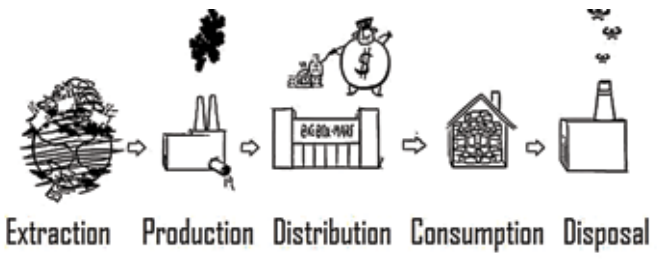


**Figure 1:** Linear Approach to Material Extraction and Disposal

Some important questions for India to understand as its economy grows rapidly and urbanisation is set to grow exponentially are –

- *What is the strategy planned for the 100 odd smart cities that are being proposed ?*
- *Are Landfills & Incinerators technically sound and financially viable options for India ?*
- *Have Frugal Context Specific solutions been explored or is there an obsession with solutions which have succeeded in a Western Context ?*

## Decentralised Operations and Source Separation of Waste

The magnitude of the problem confronting rapidly growing cities in India can be reduced significantly by practising segregation of waste at source itself. A model needs to be developed by municipal authorities in partnership with RWAs in authorised colonies as well as through citizen initiatives in unauthorised colonies and slums. Many landfill sites owing to the lack of an effective waste recycling system, solid waste is burned without segregating bio-degradable waste from non-biodegradable waste. This leads to the release of toxic gases that cause acute respiratory diseases and environmental degradation.

## Segregation and Recycling of Waste

Segregation of waste should occur at the colony or neighbourhood level, when the waste is collected. The dhaloas in the metropolitan cities are always overflowing due to lack of segregation. Recyclable waste such as construction and demolition waste, organic waste like household garbage, toxic waste like medical waste, are all mixed together. Most of the construction and demolition waste can and must be recycled. These should not reach the landfills to begin with. The municipal bodies should learn from successful zero waste systems which have been implemented elsewhere in the world where almost all C&D waste is recycled. Basic principles from these learnings combined with substantial customisation to the Indian context needs to be the cornerstone for creation of aesthetic zero waste settlements.

## Environmental Hazards

Most of the landfills in India have not been built according to accepted specifications. And owing to the decomposition of inorganic waste, the ground water is contaminated. When

rainfall percolates through the waste in a landfill, there is also the problem of leachate because most of these dumping grounds are not scientific landfills. A study by scientists at the School of Environmental Sciences in Jawaharlal Nehru University found high levels of nickel, zinc, arsenic, lead, chromium and other metals in the solid waste at landfills in metro cities, especially in Delhi. Nearly 20% of methane gas emissions in India is caused by landfills. Travel past one of these landfills and you are bound to see great spirals of smoke climbing the horizon, as the trash catches fire due to the heat generated by the decomposition of waste.

Before embarking on plans to clean up cities, what is essential is that the government formulate an integrated waste management system that ensures segregation and recycling. All waste that can be processed needs to be converted into recycled or reusble material. 100% recycling of materials is possible and there should be no necessity of landfills. To illustrate this issue, one must look at health of water bodies in India's booming tourism, business and manufacturing centres.

**Indian cities produce nearly 40,000 million liters of sewage every day and barely 20% of it is treated, according to "Excreta Does Matter", a report released by the Centre for Science and Environment (CSE).**

**Figure 2:** Health of India's Water Bodies

### Health of Water Bodies in India

In addition to handling of solid waste, there is a big challenge of managing sewage. Indian cities produce nearly 40,000 million litres of sewage every day and barely 20% of it is treated, according to "Excreta Does Matter", a new report released by the Centre for Science and Environment (CSE). Eighty percent of sewage in India is untreated and flows directly into the nation's rivers, polluting the main sources of drinking water. Weak or non-existent enforcement of environmental laws, rapid urban development and a lack of awareness about the dangers of sewage are all blamed for water pollution. A 2011 survey by the Central Pollution Control Board revealed only 160 out of nearly 8,000 towns had both sewerage systems and a sewage treatment plant. In addition, thousands of small factories were dumping untreated sewage into rivers and toxic waste was being mixed with fresh water.

There is a need to critically examine the present practice in conventional sanitation of using copious quantities of freshwater to transport domestic waste. There is substantial evidence to indicate that (a) the huge demand of freshwater for cities, (b) use of drains as evacuation channels for sewage and (c) the discharge of untreated sewage into rivers is killing Indian rivers and we may be staring at a freshwater crisis of unimaginable scale in less than a decade. Almost the entire country has nitrate levels higher than the prescribed levels -- a result of sewage leaching into groundwater supplies. Environmentalists consider that inability to regulate the use of freshwater as a cause of impending water scarcity - with the country's annual consumption expected almost to double by 2050. Researchers working on public health fear that the untreated waste dumped into rivers seeps into groundwater and is thereby creating a ticking health bomb in India.

**In fact, the issue of health of water bodies is linked to much larger issues including :**

- *How much energy and water do our cities really need ?*
- *What are sustainable mechanisms of addressing water and energy needs ?*
- *Is it important to maintain Natural Flow of Rivers*
- *Is there an important ecological function being performed by Natural Drains ?*
- *What are the Cycles of C, N, P, K and how can they be supported ?*

### Need to adopt Closed Loop Approaches

Going forward, there is an urgent need to adopt Closed Loop Approaches. Waste generation and consumption needs to become a cyclical process, mimicking the way nature does this task. There is a need to understand the resource cycle from a new ecological perspective. One such approach is that of Closed Loop Systems. Paul Hawken in his book "The Ecology of Commerce" made a very pertinent comment "*Packaging lasting for four hundred years that is kept on the shelf for two months for a product that we consume in two minutes is senseless*." The most important aim of Closed Loop environmental solutions is to divert resources from landfill and wastes from fresh water bodies. In supply chains such a process is done by closing the loop by pairing the process of forward (forward supply chain) with reverse logistic (reverse supply chain). Every aspect of consumption in the city needs to be touched to create a zero waste system.

In the EU, there is a directive principle called "Extended Producer Responsibility" (EPR) - a waste management system where the manufacturer is responsible for a product's disposal. In Canada a close cousin of EPR called Extended Product Responsibility directs a shared responsibility between the manufacturer and the government to recycle. In India, we need to develop our own indigenous approaches to ensure that waste from industrial and

domestic sectors does not ruin our soil, air and water. Before implementing a new system for managing urban waste in India, in addition to sound sustainability strategy and planning, the cultural acceptance of solutions needs to be understood.

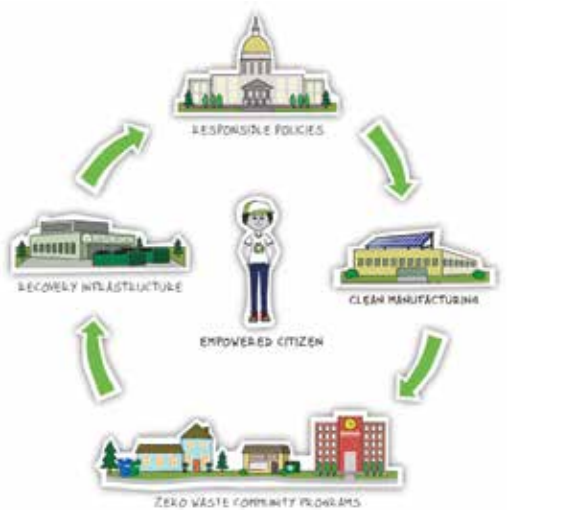


**Figure 3:** Zero Waste Systems

### Towards a new Design of Water & Sanitation Systems

The conventional modern water supply system is based on providing piped water of potable quality with multiple connections to households. While this system empowers citizens through drudgery reduction, it produces large volumes of diluted wastewater from homes. Also it renders the process of separation and treatment of wastewater more complicated (Wilderer, 2001). To treat the large volumes of waste water, centralized wastewater treatment systems and massive infrastructure is required, which has high cost implications, particularly in developing countries context (Grau, 1994). In a highly developed nation such as USA, it is estimated that 126 billion liters of domestic wastewater is treated each day at an annual cost of $25 billion (WIN reports, 2001). The investments in wastewater treatment in high GNP countries are very high as compared to other countries. However, the systems and scale adopted by the developed nations cannot be replicated in countries with low GNP since they would be inappropriate in many ways. It has been reported by some studies (Gijzen and Ikramullah, 1999) that the time period to generate the required capital investments by low GNP nations to meet the effluent standards of developed nations, exceeds by far the economic life span of these treatment plants and sewer management infrastructures. According to the reports of Central Pollution Control Board (CPCB), India, 16,000 MLD of wastewater is generated from class 1 cities (population> 100,000) and 1600 MLD from class 2 cities (population 50,000 – 100,000) and that only 4000 of the 17600 MLD of the urban wastewater generated in India is treated. The CPCB has estimated that the projected wastewater from urban groups may cross 120,000 MLD by 2051. In addition, the rural population of India alone is expected to generate not less than 50,000 MLD of wastewater by the year 2051.

Present day wastewater systems are not designed to treat wastewater and dispose waste safely to ensure health and hygiene and their operation is far from ecological in its method. In India, as in industrialized countries, using water as a medium, sewage is transported to a centralized wastewater treatment plant for purification. The cost of treatment of per unit volume of waste water in the centralized waste water treatment facilities is more than the cost of per unit volume fresh water supply. The lack of willingness of end users to pay for the waste treatment results in high cost and complexity of ensuring sustainable wastewater collection and treatment systems. With the increasing adoption of modern "flush and forget" type of sanitation systems, the nutrients present in excreta are adversely polluting the environment as waste water effluent discharge. From a resource perspective, the mixing of different flows in these systems reduces the possibility of reuse of water. Besides the nutrients present in wastewater cannot be utilized for soil enrichment (Ashley et. al., 2011).

The goals for wastewater treatment should move beyond the protection of human health to include optimal use of nutrient resources and minimizing energy consumption in wastewater treatment (Butler, 1997). Increasing interest in these technologies had led to several studies and practical implementation of various technologies taking into consideration energy use, material and chemical requirements and environmental impact of a particular technology (Norin, 1996). Worldwide, there is increasing interest in identifying solutions for managing feces and urine in an ecological manner. Separation of flows of urine and feces starting at the household level can improve the opportunities for recycling and reuse. New technical solutions such as source separation of feces and urine and reuse of fecal sludge and human urine in agriculture will help in resource utilization. This has become a field of research and practice called Ecological Sanitation and has been defined as a man-nature metabolism system dominated by technological and social behaviour, sustained and vitalized by ecological process. It deals with human settlements, waste management, hygiene, health care and agricultural system (Rusong, 2002).

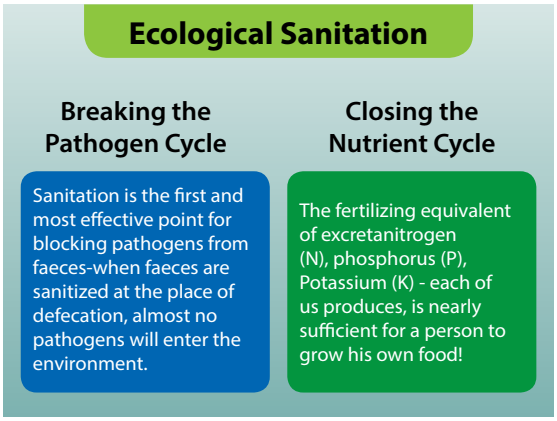


**Figure 4:** Closed Loop Sanitation Systems

To achieve the goals of ecological sanitation, the major shortcomings of the current concept of centralized waste water management need to be overcome. This will be possible only if there is a radical questioning of current practices and development of new ecologically sound concepts and approaches to ensure sustainable waste treatment and management. In ecological sanitation, establishment of effective water institutions, development of modern low-water usage and dry sanitation systems and extensive use of resource recovery and re-use approaches for wastewater are favoured (Esrey *et.al.*, 1996). The techniques and strategies proposed by ecological sanitation are holistic in approach, since feces and urine are considered to be a resource and their management linked to that of water resources and of nutrients. In fact, resource recovery and re-use approaches could, in addition to water savings, result in financial incentives which can be used to cover part of the cost of wastewater treatment.

### Waste as Nutrients

Household waste is composed of two components, namely, black water and grey water. While the waste output from the toilets is known as black water, waste generated from bathrooms and kitchens is categorized as grey water. The major proportion of total household wastewater is greywater, but the nutrient capacity of this water is minimal apart from organic components. Several studies have reported that for proper nutrient recovery and utilization, separate treatment of blackwater and greywater is required, which is a basic feature of ecological sanitation systems. By adopting ecological sanitation systems for wastewater treatment, over 50% reduction in water consumption for sanitation can be achieved (Jenssen, 2002).

### Waste Management in Proposed Smart Cities

Currently, there is great thrust on urbanisation and Smart Cities. However, the Smart Cities agenda needs to proceed with a greater integrated vision. Let us take the example of GIFT City – which has adopted a pneumatic underground waste collection system to transport waste from multistorey buildings to a collection centre at a speed of 110-140 km per hour. This system, as the Swedish manufacturer described it on the company website, is "a minimum requirement for Smart City Concept and Initiative across India."While data about the cost or benefits of the automatic waste collection system are not available, research by the University of Helsinki in 2012 on similar technologies in the Finnish capital provides a fair idea about the costs involved. A vehicle-operated door-to-door waste collection system is economically six times superior to pneumatic systems because of the high investment.

### Concluding Remarks

Although overall, the scenario of solid waste and water bodies in India is not very promising, there are a few silver linings which hold out hope for the future. This article is being concluded by saluting some undefatigable champions who have been working for a clean and green India. Also highlighted are two frugal technology innovations which are representative of many more which we need to support to create a country with abundant water and high consciousness regarding the environment.

### Silver Lining 1 : Ambassadors of Clean Green Habitat

The silver lining in this otherwise challenging scenario in India is the work done by several passionate individuals and organizations, some of whom are listed below -

- Saru Waghmare, Kagad Kach Patra Kashtakari Panchayat
- Almitra Patel, INTACH Water Network
- C Srinivasan, Indian Green Service
- Ravi Agarwal, Toxics Link
- and many more …

### Silver Lining 2 : Soil Bio Technology - Frugal Innovation in WM

A notable frugal innovation in recovering precious freshwater in urban context is Soil Bio Technology developed by Prof HS Shankar of IIT Bombay. SBT is based on the understanding that the energy needed to supply oxygen to a soil environment is a fraction compared to energy needed to supply oxygen to an aquatic environment. SBT is the outcome of long years of reflection to answering one key question, "if natural elements can help purify water to produce crystal clear water in mountain springs, can the same process be replicated and catalysed?" This is the inspiration for SBT and related technology developmental work. SBT Technology finds immediate applications in water harvesting, sanitation, agriculture, forestry and fisheries. Developmental studies in SBT type environment for water purification show that through appropriate adjustment of process conditions COD, ammonia, nitrite and nitrate, arsenic and iron removal can be achieved as required. Another very interesting feature of the process is that waste water with near zero dissolved oxygen emerges nearly saturated with oxygen and this is achieved without use of mechanical aeration. In SBT formulated soil such as media, culture and additives are used in a green environment wherein oxygen required is generated internally so as to bring about organic waste processing at desired organic and hydraulic loading onsite. SBT based plants have very low operating costs and its choke-free design leads to very low downtime for maintenance and a very green landscaped appearance - all of which is in direct contrast to conventional wastewater treatment plants. SBT is covered by Indian and US patents and is now being offered globally by Vision Earthcare P Ltd – an IIT Bombay incubated startup. Several such SBT facilities working with raw sewage of sizes 500 lit/day (individual homes) to several million litres per day ( large communities) have been set up during last 10 years. A 3 million litres per day facility set up for Municipal Corporation of Bombay is featured in a documentary produced by Government of India and can be viewed at the following websites: http://www.che.iitb.ac.in/faculty/hss/hss-web.html.

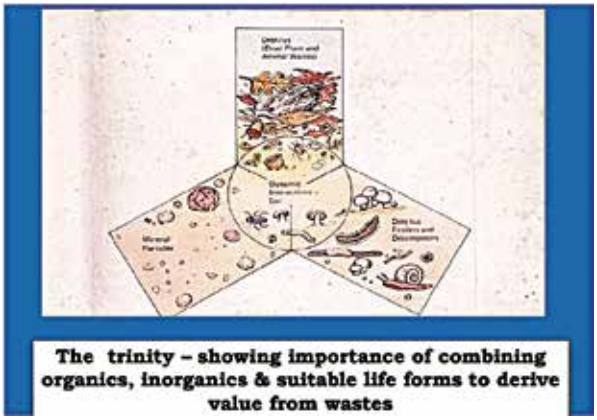


**Figure 5:** Soil Bio Technology developed by Prof H S Shankar, IIT Bombay

### Silver Lining 3 : Frugal Innovation in Sanitation - Zerodor Waterless Urinals

With increasing emphasis on water conservation, there is renewed interest in toilets and urinals designed to minimize the amount of water consumed in flushing to mitigate excessive demands on water supplies as well as on waste water disposal systems. Waterless Urinals currently require regular replacement of parts for their continuous operation. These traps also require periodic maintenance routines to prevent blockages. In order to overcome these issues, IIT Delhi has developed and patented a waterless Urinal Technology "**Zerodor**". Zerodor Waterless Urinals is a chemical free technology, costs one fifth the cost of competing technologies and has no recurring cost which makes it a much more attractive proposition. In addition there is an advantage in this technology of being able to retrofit into existing urinal pans. Waterless Urinals do not require water for flushing and result in saving anything between 56,800 litres to 1, 70,000 litres of water per urinal per year. In addition, touch free operations reduce the spread of communicable diseases.

Ekam Eco Solutions has taken Waterless Urinal Kiosks and Wastewater Treatment Systems to market. Zerodor Waterless Urinals are covered by Patents and are now installed across the world by Ekam Eco Solutions P Ltd – an IIT Delhi incubated startup URL : www.ekamecosolutions.com


**Figure 6:** Zerodor Waterless Urinals Technology developed by Dr V M Chariar & S Ramesh Sakthivel, IIT Delhi

One can conclude this article by stating that probably integrating high technology waste collection systems with existing city infrastructure is highly challenging. In Indian cities, given the low labour cost, probably the economic advantage of waste collection by training and upgrading informal sector workers already involved such as garbage pickers, kabadi-wallahs, sanitary workers, informal sector would be even greater. In the absence of informed research and faced with enticing Smart City propaganda, it is not clear whether city administration and ULBs would be able to make the best rational choices? In view of the high level of diversity in urban places – economic, social and cultural, it is important that multiple approaches must be available for ensuring transition to zero waste settlements. It needs to be emphasised that the service sector, slum dwellers, homeless and the poor need to be incorporated into the vision of growth of modern cities – would the creation of vibrant growth engines translate into the elimination of poverty or does it risk further marginalising the poor ?

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# Wireless Sensor Networks and the Internet of Things: Technologies, Applications and Challenges

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Indian Institute of Technology Delhi

Wireless sensor networks (WSN) typically consist of spatially distributed sensing nodes that monitor certain physical parameters or environmental conditions, cooperatively pass their data to a gateway (through multi-hop connectivity) and can also enable control of sensor activity or the activity of other devices. Sensor nodes can range in size from that of a "shoebox" drawing power in the order of Watts [1], right down to "dust-scale" nodes drawing power in the order of micro-Watts[2]. The proliferation of these devices creates the Internet of Things (IoT), where sensors and actuators blend seamlessly with the environment around us. This article highlights areas for research and innovation opportunities and interventions which might be appropriate for unlocking the full potential of WSN.

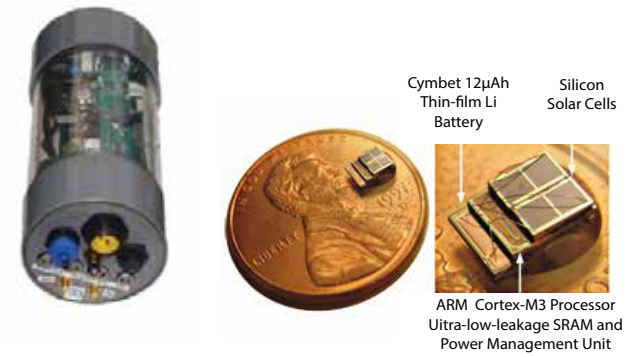


**Figure 1:** Sensor nodes at the two ends of the dimension scale: (a) 90 mm x 200 mm [1] (b) 8.75 mm3[3].

**Platform hardware**: A multitude of WSN platforms are available in the market which can be classified as research/prototyping platforms and commercial platforms. Platforms under the former class include those based on IEEE 802.15.4, low-power Wi-Fi, Bluetooth low energy etc. On the other hand, commercial platforms are closed solutions specific to one manufacturer or consortium of manufacturers that include sensors, gateway devices and supporting software. The latter implement different standards and proprietary protocols so interoperability among them is limited.

**Communication protocols/stack**: There are many competing communication technologies and standardisation efforts are an ongoing activity, with there being no widely accepted protocol stack for WSNs. The IEEE 802.15.4 is a wireless standard for low-power and low data rate applications. It specifies the physical (PHY) and medium access control (MAC) layers and forms the basis for ZigBee, ISA 100.11a, WirelessHART specifications, each of which extends IEEE 802.15.4 by defining the upper layers.

6LoWPAN (or IPv6 over Low power Wireless Personal Area Networks) originated from the idea that low-power devices with limited processing capabilities should be able to participate in the IoT and the Internet Protocol (IP) should be applicable even to the smallest devices[4]. To expose the full potential of WSNs in the IoT context, WSNs will require connectivity to the Internet. 6LoWPAN is an adaptation layer which compresses IPv6 headers to minimise the size of wirelessly transmitted packets. However the current state of the Internet - in a migration phase from IPv4 to IPv6 - hinders integration of WSNs with the Internet using 6LoWPAN.

The ZigBee Alliance publishes several application profiles that define a domain space of related applications and devices, allowing multiple OEM vendors to create interoperable products. ZigBee IP, an IPv6-based solution for providing seamless Internet connectivity to low-power devices, was made public in March 2013. It was designed to specifically support the Smart Energy Profile 2.0 (SEP 2.0) and other ZigBee application profiles do not make use of it. Recently, the IEEE adopted the SEP 2.0 application standard as the IEEE 2030.5-2013 standard. Although the ZigBee community is very active and involves various large industry actors, scalability is an issue in dense deployments, devices are fully interoperable only within an application profile and most application profiles are not IP-based.

For many years, Wi-Fi technology was not considered as an option for low-power devices as it was designed for high bandwidth applications without considering energy efficiency. There have been efforts to optimise standard Wi-Fi chips for power consumption, while retaining the advantages of easy integration with existing infrastructure, support for proven encryption and authentication techniques and IP-network compatibility. Some companies have even developed System-on-Chip (SoC) solutions for low-power Wi-Fi but it did not gain much traction. The IEEE 802.11 working group has initiated a project, called IEEE 802.11ah, to enact a standard (by end-2016) at sub-1 GHz unlicensed bands without considering backward compatibility.

Bluetooth is a wireless standard for exchanging data over short distances (~10 m) creating personal area networks while maintaining high levels of security. Bluetooth low energy (BLE), merged into the main Bluetooth standard in 2010, is optimised for devices requiring maximum battery life. BLE has been gaining

momentum as a technology for wearable computing such as fitness devices and on-body sensors.

**Network and data management**: Network management refers to the process of monitoring, managing and controlling the behaviour of a network to ensure it meets the desired level of performance[5]. WSNs can be highly dynamic and prone to various types of faults. Currently WSN management systems and tools are designed for specific needs and do not provide a fully integrated view of the network. Thus, there is a need for network management system/tool for WSNs that is compatible with multiple wireless technologies, compatible with products from a variety of manufacturers and covers the entire lifecycle of a WSN from design, configuration, monitoring and managing the network.

As the IoT becomes a reality with the deployment of a large number of sensor devices and a networked infrastructure, it will result in the availability of an immense amount of heterogeneous data allowing us to measure and understand physical phenomena and natural events. For developing applications and services independent of a particular WSN deployment, improving the usability and accessibility of the sensor data is a vital step which can be achieved by enriching the data with semantic information. In the last few years, semantic web technologies have been developed to alleviate the issue of semantic interoperability in heterogeneous network environments. The World Wide Web Consortium (W3C) has undertaken the Semantic web initiative and developed a common framework for sharing and reusing the data from heterogeneous sources across application, enterprise and community boundaries.

**Application areas**: The evolution of sensor networks has been largely driven by the applications that can benefit from the sensor network technology. Some of the key application areas are:

1. **Energy management:** As the cost of energy generation and its environmental impact increases, there has been a push to save energy by improving the energy efficiency of various systems. Through the use of wireless sensors, measuring energy at key points and controlling or actuating different devices becomes possible. Life expectancy of battery-powered sensors is a concern and energy harvesting technology could be the key.

2. **Healthcare:** Wireless sensing has expanded the spatial and temporal scope of medical sensing and enabled a diverse set of delivery mechanisms. Challenge for WSNs are the stringent requirements on system reliability, quality of service (QoS) and particularly privacy and security.

3. **Industrial automation:** Industrial applications currently rely mainly on wired sensor systems and have stringent requirements for metrics such as latency/delay and reliability. Challenges in an industrial environment include wireless communications in a high-noise radio environment, durability of hardware/equipment in the operating environment and the need to adhere to industry standards and certifications for the deployed equipment.

4. **Transportation:** WSNs can provide continuous monitoring during the transportation process assuring quality, safety and security of goods being transported. In addition, WSNs can be used as part of an intelligent traffic monitoring and management system. A typical challenge would be to deal with mobility. In addition, the devices may have to be compliant with automotive standards.

5. **Agriculture and environmental monitoring:** Wireless sensors have allowed us to acquire real-time, geo-referenced and fine grained environmental data with a large spatial and temporal spread, even from remote locations. Near real-time information about weather and environmental conditions can enable better timing and control of agricultural management practices such as irrigation and pesticide spraying. It is important to choose appropriate parameters for monitoring in agriculture applications and design systems that can interpret data and recommend a course of action.

6. **Emerging applications such as smart grid and smart cities:** Smart grid is envisioned as a modern electrical grid that uses information and communication technology (ICT) to improve reliability and save energy by improving efficiency of electricity production and distribution systems. Given the large-scale and pervasiveness of the smart grid infrastructure and components, interoperability, open standards and security will be the key challenges. Smart cities aim to improve citizens' quality of life and the efficiency of services provided by governing bodies and businesses by using ICT. Since smart cities would integrate many of the existing systems, interoperability, security and privacy would be the critical challenges.

**Discussion and Summary**: Below we highlight some of the key challenges that need to be overcome for a wider adoption and commercial success of WSNs, which would take us towards the Iot.

1. **Deployment costs vs. benefits:** Many of the WSN research studies focus on the savings (energy, installation cost etc.) from the deployment of a WSN, but do not report the cost of sensor devices or the expected length of time over which the cost could be recovered. On the other hand, for many years, market research studies have been predicting the unit cost of sensor devices to drop to $10 range, but most current devices cost about an order of magnitude more. There is also a need to account for benefits resulting from improvements in comfort/lifestyle and productivity.

2. **Interoperability:** Open standards will be crucial for widespread adoption of WSN technology. Interoperability both in terms of wireless technologies and standards as well as sensor data formats and semantics would be required for developing smart applications over large-scale networks such as smart grid and smart cities.

3. **Reliability/QoS:** As WSN applications have evolved over the years, the performance requirements from WSN technology have also increased. There is a need to define specific application characteristics and QoS requirements to facilitate optimised network planning and performance.

4. Ease of deployment and use: The deployment and use of WSNs has to be easy enough to be carried out by people without specialised training. Even in cases where it might be possible to have specialised personnel to deploy WSNs, the programming and configuration of the sensor devices needs to be simplified in terms of ease of use. For seamless integration of devices and services of different vendors and using different technologies, standardised service discovery protocols would have to be adopted. Integration with legacy or existing wired systems and/or backend IT systems will also be vital.

5. **Power management:** Energy consumption of the sensor device is a significant challenge in many WSN applications. Two commonly used approaches for reducing energy consumption are duty cycling and adaptive sampling. Another solution is the use of energy harvesting technology to extract energy from ambient sources.

6. **Security:** Resource limitations on sensor devices make security in WSNs a challenge. As WSNs find application in critical areas, security is increasing in importance and lack of security mechanisms would inhibit commercialisation.

In this article, we have identified a range of open issues that we perceive still exist within the WSN technology space and that hinder widespread adoption of the technology. We also point to a number of areas where we believe innovation is necessary to advance the WSN and the IoT technology.

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Smart Cane receives National Award on December 3

Industry-Academia Interaction during IISF @IIT Delhi on December 7

### Abbreviations

AM: Department of Applied Mechanics,
BSTTM: Bharti School of Telecommunication Technology and Management,
CARE: Centre for Applied Research in Electronics,
CAS: Centre for Atmospheric Sciences,
CBME: Centre for Biomedical Engineering,
CES: Centre for Energy Studies,
CRDT: Centre for Rural Development and Technology,
CPSE: Centre for Polymer Science and Engineering,
CE: Department of Civil Engineering,
ChemE: Department of Chemical Engineering,
Chy: Department of Chemistry,
CSE: Department of Computer Science and Engineering,
DBEB: Department of Biochemical Engineering and Biotechnology,
DMS: Department of Management Studies,
EE: Department of Electrical Engineering,
HUSS: Department of Humanities and Social Sciences,
IDDC: Instrument Design Development Centre,
ITMMEC: Industrial Tribology,
KSBS: Kusuma School of Biological Sciences,
ME: Department of Mechanical Engineering,
Phy: Department of Physics,
TT: Department of Textile Technology

# Faculty Profiles

**Prof AS Rathore**
Department of Chemical Engineering
Indian Institute of Technology Delhi

Anurag S Rathore is a Professor at the Department of Chemical Engineering, Indian Institute of Technology, Delhi, India. He holds a BTech in Chemical Engineering from Institute of Technology Delhi (1994) and a MS (1995) and PhD (1998) in Chemical Engineering from Yale University, New Haven, CT, USA. Prior to joining IIT Delhi, Prof Rathore held technology leadership positions at Pfizer Corporation (1999-2003), St Louis, Missouri, USA and Amgen Inc (2003-2009), Thousand Oaks, California, USA.

Prof Rathore's research focuses on solving problems faced in the manufacturing of human therapeutic biotech drugs. The complexities associated with manufacturing of biotech drugs demands that this problem solving be accomplished in collaboration with other experts in the institute, outside the institute, the biotech industry and the domestic and international regulatory agencies. Topics that are presently targeted include: Quality by Design (QbD) based process design, Process Analytical Technology (PAT) based process control, Multivariate data analysis (MVDA) of bioprocessing data, Continuous processing for production of affordable biotherapeutics, Mechanistic modeling of bioseparations unit operations, Characterization of biosimilar products and Stability of biotech therapeutic products.

Prof Rathore has authored more than 400 publications and presentations in the above mentioned areas. He is presently serving as the Editor-in-Chief of ***Preparative Biochemistry and Biotechnology*** and Associate Editor for ***Journal of Chemical Technology and Biotechnology and PDA Journal of Science and Technology.*** He also serves on the Editorial Advisory Boards for ***Biotechnology Progress, BioPharm International, Pharmaceutical Technology Europe and Separation and Purification Reviews.*** Dr Rathore has edited five books titled ***Quality by Design for Biopharmaceuticals: Perspectives and Case Studies*** (2009), ***Elements of Biopharmaceutical Production*** (2007), ***Process Validation*** (2005), ***Electrokinetic Phenomena*** (2004) and ***Scale-up and Optimization in Preparative Chromatography*** (2003). His sixth book titled ***Preparative Chromatography for Separation of Proteins and Peptides*** will be published in 2016 by Wiley Interscience.

Teaching is a passion for Prof Rathore. Before joining Indian Institute of Technology Delhi in 2009, he taught ***Bioseparations/Bioprocessing*** at the Department of Chemical Engineering, Washington University at St Louis, MO, from 2000-2002 and then ***Bioseparations and Bioprocessing Engineering*** at the Department of Chemical and Biomolecular Engineering, University of California at Los Angeles, CA, from 2004-2008. At IIT Delhi, he will be teaching the new departmental core course titled ***Introduction to Industrial Biotechnology*** and an Advanced Elective titled ***Bioprocessing and Bioseparations***. He believes that it is for us as instructors to inspire more students to pursue core disciplines whether in industrial employment or higher education. This is necessary to create a strong science and technology framework in the country, something that can serve as a basis for launching initiatives such as ***Make in India***. To accomplish this, teaching needs to evolve from textbook teaching to a more application oriented teaching. While the students need to know the basics and the fundamentals, they also need to "see" how and where the theoretical concepts that they have learned in the course will be applied.

At IIT Delhi, Prof Rathore has established the *Bioseparations and Bioprocessing Laboratory*. This facility is capable of performing all bioprocessing unit operations that are typically used for purification of biotech therapeutics, starting from a vial of a cell bank to the final drug substance of the related biotech therapeutic. Prof Rathore has been able to generate more than 10 Crores of funding in the last 6 years and has more than 20 academic and industrial collaborators. Projects include fundamental research such as mechanistic modeling of the commonly used unit operations. Industry sponsored research remains a core focus of the research group. A key technology that has been recently awarded US patent is that of a single step purification process for manufacturing ***Granulocyte Colony Stimulating Factor (GCSF), a therapeutic drug for cancer patients***. The process developed is expected to cut the cost of production of the drug by 50-80%. Prof Rathore, together with FITT, aims to license and transfer this process to industry. Another recent success has been development of a Coiled Flow Inverter based reactor for continuous refolding of therapeutic proteins (Figure 1). The proposed process is capable of performing continuous refolding of GCSF. Filing for Indian patent has already been made and one for the US patent is underway. This invention has further been used to create a continuous process for production of GCSF (Figure 2). The process has been run non-stop for 24 hours to test feasibility and a 15 X improvement in productivity has been demonstrated. Prof Rathore is seeking industrial partners for commercializing this process.

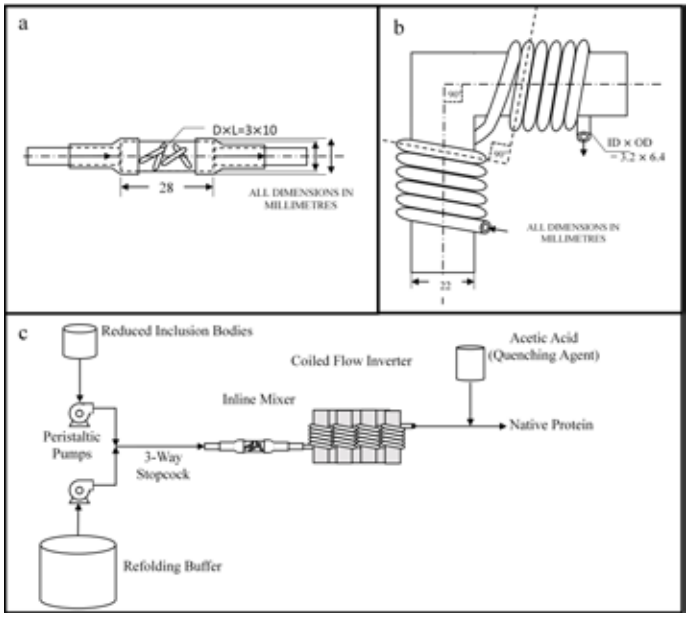


**Figure 1:** (a) Illustration of the dynamic mixing unit. Connections were made through Tygon tubing of higher diameter and reinforced through cable ties. (b) Illustration of a bend for CFI. (c) Process flow diagram for the continuous refolding process. A bank is a collection of four branches, each with five turns of helix.

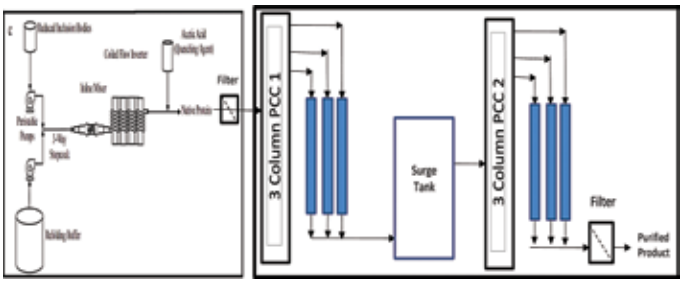


**Figure 2:** Continuous processing for production of GCSF.

Besides teaching and research, Prof Rathore closely works with major government agencies such as DBT and CDSCO on a variety of initiatives. He consults for the Drug Controller General of India (DCGI) office in evolving the regulatory framework for the biotech industry in India. He also co-authored the recently issued Guidelines on Similar Biologics: Regulatory Requirements for Marketing Authorization in India by the Ministry of Health, Government of India. This is a critical guideline for ensuring successful production of biosimilar drugs by the Indian biotech industry. He chairs the Committee for Advising the DCGI on Regulation of Biotech Products (r-DNA product), Ministry of Health and Family Welfare, Government of India and serves in the Management Advisory Committee for BIRAC Bio-Incubator at NCR Biotech Science Cluster Faridabad, BIRAC, Department of Biotechnology. Recently, he has been appointed in the Scientific Expert Committee for the National Institute of Biologicals.

Earlier in 2015, DBT awarded a Center of Excellence (COE) in Biopharmaceutical Technology. Prof Rathore is serving as the Coordinator of the COE together with fifteen faculty from six academic units. The focus of the COE is on serving the Indian biopharmaceutical industry to ensure India becomes the global hub of manufacturing economical, safe and efficacious therapeutics. This COE will be creating technology solutions that make our biopharmaceutical industry more competitive globally, form technology partnerships with the industry in implementing these solutions, perform the much needed manpower training and participate in policy development through dialogue with relevant agencies such as CDSCO and DBT to ensure that our regulations are aligned with the needs of the patients as well as with the global quality expectations.

In summary, Prof Rathore strongly believes that collaboration is key to success in research today. Most of the problems that we face in biotechnology require a multifunctional expertise to create a successful solution. He feels that to become the premier research institute and have a meaningful impact on societal problems, we need to embrace the spirit of collaboration.

## Professional Candidate Registration Programme

Applications are invited from qualified professionals working in industry and research organizations for a unique knowledge augmentation and skill enhancement programmes at IIT Delhi. This involves a semester-long registration for a regular PG course. Course fees ranges from Rs. 15,000/- to Rs. 20,000/- (industry professionals) and Rs. 6,000/- to Rs. 8,000 (academic/government personnel) for a 42 hour lecture course. In the case of a few selected courses, on-site course delivery using the two way audio-video link can be considered. All major disciplines of Science and Engineering and also relevant courses from the Humanities, Social Sciences and Management streams which are being conducted at IIT Delhi are covered. The course detail can be downloaded from FITT website www.fitt-iitd.org.

Eligibility: Degree in Engineering or Masters Degree in Science, Management or any other Post Graduate Degree with relevant industry experience. The two semester sessions in the academic year starts in the month of July and January, the exact dates being notified in advance.

Contact: uttamaswal@hotmail.com, kirityroy@yahoo.com

**Prof PR Panda**
Department of Computer Science and Engineering
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## Brief Biography

Prof Preeti Ranjan Panda was born in the town of Berhampur in the Ganjam district of Southern Orissa and did his early schooling there in St. Vincent's Convent School and Khallikote College. He received his BTech degree in Computer Science and Engineering from the IIT Madras in 1990. After spending three years at Texas Instruments in Bangalore, he proceeded for higher studies in Information and Computer Science at the University of California at Irvine, from where he received his MS and PhD degrees. After completing his PhD, he was employed at the Advanced Technology Group in Synopsys Inc, Mountain View, USA, during which he also a visiting scholar at Stanford University. He is currently a Professor in the Department of Computer Science and Engineering at IIT Delhi.

## Research

Prof Panda's early research work focused on High-level Synthesis (HLS), the process of automatically generating efficient electronic hardware from high-level specifications. He made research contributions in several areas of HLS, including system modelling of DRAM, estimating controller delay and making intelligent loop transformation choices. During his stay at Synopsys Inc. Prof Panda was involved in defining and working out the synthesis implications of *SystemC*, a system specification language that has since been widely adopted in industry and academia as the standard language for high-level modelling of complex Systems-on-a-Chip.

As a follow-up to HLS research, Prof Panda continued the design space exploration problem by extending the investigation of automatic system generation to include complex components such as memories. The ensuing work was instrumental in establishing the foundations of memory exploration and optimisation in embedded systems. Embedded systems offer the exciting opportunity to customise system architectures according to the requirements of the application. In his research, he investigated ways to customise different aspects of the memory subsystem in embedded systems. His PhD dissertation and early papers in 1997 introduced the concept of *Scratch Pad Memory* and formulated ways to partition on-chip memory space between scratch pad memory and cache. This work played a significant role in influencing the problems and solution techniques proposed by the system design research community. Prof Panda has continued the investigation of such software-controlled memories in recent times, with his research on programmable scratch pad memory and software caches and low-power vector processors.

Prof Panda's ongoing research includes a major focus on energy-efficiency in computing systems. Modern computer systems – spanning across the spectrum from embedded systems to server machines – need mechanisms to react to dynamic power and energy constraints arising out of different practical scenarios, including user preference settings and battery levels. Since standard power-saving mechanisms also lead to reduced performance, an important question that arises in this context is, what is the best response by the run-time environment to this high level directive? In collaboration with Intel, Prof Panda's research group is studying approaches involving a fine-grained adjustment of several system components such as caches, voltage/frequency settings and DRAM. These approaches include the possible application of machine learning formalisms to computer architecture decisions.

Another line of research by Prof Panda's research group currently is Post-silicon Validation. Robust validation methodologies play a vital role in the semiconductor chip design flow, as the industry struggles to contain costs under increasing design complexity. In his research sponsored by Intel and Freescale Semiconductors, Prof Panda's group has worked on scalable debug methodologies that anticipate a large number of processor cores in future SoCs and processors and are sensitive to the associated requirements of handling large amounts of debug data, area constraints, as well as awareness of an inherent heterogeneity in such systems in terms of different types of processors, memories and accelerators.

Along with colleagues in the department of CSE, Prof Panda has co-guided eight PhD students under his supervision and leads a team of six doctoral researchers. He has delivered seminars on his research work at several institutions including Stanford University, Carnegie Mellon University, Technology University of Munich, TU Dortmund, EPFL, Seoul National University and National University Of Singapore and has delivered tutorials in leading conferences including ICCAD and ASPDAC.

## Industry Collaboration

Prof Panda has played a significant role in establishing and maintaining research linkages between IIT Delhi and the Indian Semi conductor Industry over the years. Firmly believing that a great opportunity exists in co-opting industry in the identification of future generation engineering research challenges, Prof Panda has reached out to several major companies such as Intel, IBM, Freescale Semiconductors, the Semiconductor Research Consortium and Calypto Design Systems, all of whom have

generously sponsored IIT research. These fruitful collaborations have resulted in relevant futuristic research problems for IITD, jointly supervised PhD dissertation for instance in case of IMEC Research Lab, Belgium, opportunities for PhD students as research interns and taking up employment in the industry.

### Text-book Writing

Prof Panda has spent some effort writing graduate-level text books in his area of research interests. His first book, *Memory issues in Embedded Systems-on-chip*: *Optimizations and Exploration* (Kluwer Academic Publishers, 1999) has served as a significant reference on the state-of-the-art of memory research in system design. His second book, *Power-efficient System Design* (Springer, 2010), captured a summary of energy-efficiency issues in computing systems and has been used as a textbook in an undergraduate course on Low Power Computing at UCLA.

### Awards and Honours

Prof Panda's paper, Data and memory optimization techniques for embedded systems, ACM TODAES, 6(2), 2001, has been recognised as the most downloaded paper of the year of ACM TODAES journal for several years now. Other recognitions received by him include a Best Paper Nomination at the International Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS), an Honourable Mention Award at the International Conference on VLSI Design, an IBM Faculty Award and a Department of Science and Technology Young Scientist Award. Research supervised by him in the area of Low Power Computing was adjudged the winner of Intel Scholar Challenge. He also received the UC Regents Fellowship for his doctoral dissertation and secured the 1st rank in the +2 Science stream examinations conducted by the Council of Higher Secondary Education of Orissa state.

### Research Community Service

Prof Panda has served on the editorial boards of the major journals in the areas of Design Automation and Embedded Systems, including IEEE Transactions on Computer Aided Design of Integrated Circuits and Systems (TCAD), ACM Transactions on Design Automation of Electronic Systems (TODAES) and International Journal of Parallel Programming (IJPP) and as Technical Program co-Chair of the IEEE/ACM International Conference on Hardware/Software Co design and System Synthesis (CODES+ISSS) and International Conference on VLSI Design and Embedded Systems (VLSI Design). In 2014, he co-organised in the Delhi area the IEEE/ACM Embedded Systems Week, a prestigious international research forum in the discipline, consisting of several top conferences such as CODES+ISSS, CASES and EMSOFT. He has also served on the technical program committees and chaired sessions at several top research conferences, including DAC, ICCAD, DATE, CODES+ISSS, EMSOFT, ISLPED and IPDPS. Other research community service activities engaged in by Prof Panda include panel member for selecting the ACM SIGDA Outstanding PhD Dissertation of the year and the EDAA Best PhD Dissertation of the year.

In his spare time, Prof Panda makes half-hearted attempts to keep in touch with Indian music and travel.

21st AGM of FITT at the Senate Room on Novemmber 16


Alumni Day observed @ IITD on December 29

Indo Dutch Meeting On Data Driven Science Computational from December 10-12

Launch of Crash Data Collection Project for Safer Roads on September 18

# Innovations

## Opportunities for IP Licensing

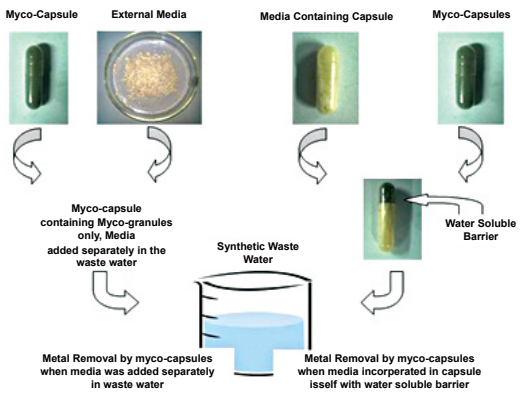
| S No | Title | PI/Dept/Center |
|---|---|---|
| 1 | Non-invasive system and method for glucose monitoring | Dr SK Jha, CBME |
| 2 | A device for measurement of electrical properties of electro-conductive fabrics | Prof K Sen, TT |
| 3 | Wireless ECG patch and system for obtaining high definition mobile ECG | Prof B Singh, EE |
| 4 | Conversion of -6-amyl-alpha-pyrone in 2-nonene-4-one via ring opening and decarboxylation | Dr MA Haider, ChemE |
| 5 | A process for synthesis of metal core-carbon shell nanoparticles | Prof BR Mehta, Phy |
| 6 | Process for expression of biologically active recombinant proteins in Escherichia Coli | Prof TK Chaudhuri, KSBS |
| 7 | A polyacrylonitrile ultrafiltration membrane for removal of arsenic and chromium | Prof GP Agarwal, DBEB |
| 8 | Evanescent wave-based illumination | Dr RK Elangovan, DBEB |
| 9 | Synthesis of 2-Aminoquinoline-3-carbonitrile | Prof AN Bhaskarwar, ChemE |
| 10 | A system and method for detecting or identifying the substances and their composition | Prof Jayadeva, EE |
| 11 | Composite fibers having aligned inorganic nano structures of high aspect ratio and preparation method | Prof A Agrawal, TT |
| 12 | Magnetic capturing of rare cells | Dr RK Elangovan, DBEB & Dr V Perumal, KSBS |
| 13 | Magnetic enrichment of magnetically marked analytes | Dr RK Elangovan, DBEB & Dr V Perumal, KSBS |
| 14 | Scar preventing wound dressing material | Prof B Gupta, TT |
| 15 | Myco-Capsules for Bio remediation of waste water | Dr A Malik, CRDT |

## Technology Profiles

### Myco-capsules for bioremediation of waste water

**Dr A Malik**
Center for Rural Development and Technology
Indian Institute of Technology Delhi

Water streams in India are getting polluted due to release of waste water from various industries, which contain mixture of heavy metals, dyes and other organic/inorganic compounds. Synthetic dyes present in the industrial effluents are recalcitrant organic compounds while heavy metals are non-degradative in nature and produce various health hazards. Specialized microbial cultures have been explored for bioremediation of industrial waste water. However, storage and delivery system for such microbial cultures is an issue (1-3). Production of microbial formulations for biopesticidal activities has been opted by many researchers (4). However, the storage of microbial formulations requires low temperature storage or refrigeration in many cases to remain active, which is difficult to attain. Such mycogranules are also susceptible to cross contamination. Although enormous research has been carried out and formulations for degradation of certain organic pollutant has been reported (5), no formulation has been reported for the dual purpose of dye and/or metal removal that can be stored and transported at ambient conditions without the loss of viability and pollutant removing ability.



The main objective of this invention is to provide a suitable formulation and a process for production of mycocapsules to target specific application i.e. metal removal, dye removal or both metal-dye removal in the waste water. The formulation comprises of fungal strains having a good shelf life at ambient conditions for removal of dyes and/or metals from the waste water. The formulation of fungal strains has enhanced stability at ambient conditions without loss in viability and pollutant removal efficiency of the fungal strain. The invention intends to provide a formulation and process that is less costly, quick and easy to produce. At the same time mycocapsules ensure elimination of cross contamination.

The present application also discloses method of preparation of myco-capsules whereby the media specific for the encapsulated fungal strain is also packed inside the capsule and a barrier is used to separate the media and the fungal strain inside the myco-capsule. The presence of inherent media inside the myco-capsules eliminates the need for providing nutritional requirements during the treatment of waste water. In addition, multiple strains in one capsule can be incorporated for better efficacy during the bioremediation process and for simultaneous removal of dye and metal. In the nutshell, the present invention provides a tool termed myco-capsules, which are carrier based encapsulated formulations of fungal strainsfor accomplishing the bioremediation of waste water contaminated with heavy metal and dye cocktails.

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## Functional Recombinant Protein Preparation in *Escherichia coli*

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Recombinant protein production in Escherichia coli is the most popular method for large-scale, rapid and cheap production of recombinant proteins for therapeutic, industrial and research applications. The major bottleneck in using E. coli as the host organism is the formation of inactive aggregates by certain proteins known as inclusion bodies. The recovery of the functional proteins from the inclusion bodies by in-vitro refolding technique is quite tedious and often very uncertain. Certain proteins also do have difficulty to achieve the native three-dimensional structural confirmation by refolding process. As a consequence, there is a requirement to fold the proteins in the cells during synthesis with the assistance from the folding modulators like molecular chaperones. Molecular chaperone families like DnaK/J/GrpE and GroEL/ES are known to assist the folding of various types of proteins including multi-domain aggregation-prone polypeptides in the cellular environment. Osmolytes like betaine, glutamate, trehalose, etc. are known to interact with unfolded protein structure to render structural stability. Our research group is working on the development of processes for the improvement of folded and functional recombinant protein preparation in Escherichia coli system. Furthermore, we have developed the tools for extensive characterisation of recombinant proteins, such as, determining its stability and shelf life, physical and chemical characterisation, propensity for aggregation, solubility, interaction with other proteins and ligands etc.

The approaches are being used to accomplish the production of functional recombinant proteins are, recombinant DNA technology, chaperone assisted protein folding process and using combinatorial approach of chaperone assisted protein folding, involvement of osmolytes and environmental stress etc.

Bacterial protein folding machinery GroEL and GroES has been reported to prevent aggregation as well as assist in the folding of several aggregation prone proteins in the cell. Our research group in IIT Delhi has been involved for more than a decade in GroEL-GroES assisted folding of aggregation prone recombinant proteins. We have reported that for few recombinant proteins, who's folding yields are extremely poor; with the assistance of exogenous GroEL-GroES assistance it is possible to enhance the yield of functional protein substantially. Thus, it is possible to enhance the production of folded recombinant protein in E.coli, using the chaperone assisted folding technique developed by our team. We have already applied for Indian patents on the tools that we have developed for the enhancement of

functional recombinant proteins in E.coli using assisted folding process (Chaudhuri TK and Gayathri R 2015, Chaudhuri TK and Goyal M 2014 and Chaudhuri TK and Dahiya V, 2012). The following cartoon presentation demonstrates the GroEL assisted folding process of an aggregation prone protein Maltodextrin Glucosidase reported by our group (Paul S, et al., 2007):

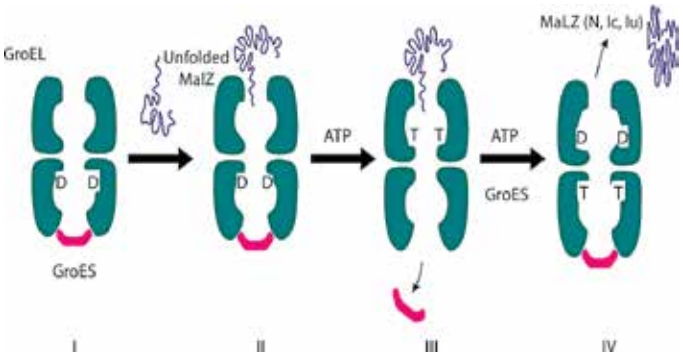


**Figure 1:** describes that the inclusion of several bioprocess strategies in combination during the recombinant protein expression can reduce the inclusion bodies formation, enhance the solubility of the recombinant protein and thereby improving the activity and the yield of functional recombinant proteins.

In this presentation, an earnest effort for the enhancement in the functional recombinant protein preparation in Escherichia coli expression system, of a severely aggregation-prone multidomain protein Mitochondrial Aconitase (mAco) (Chaudhuri TK et al, 2001; Gupta P et al., 2009) has been demonstrated in Escherichia coli system using several of the bioprocess strategies.

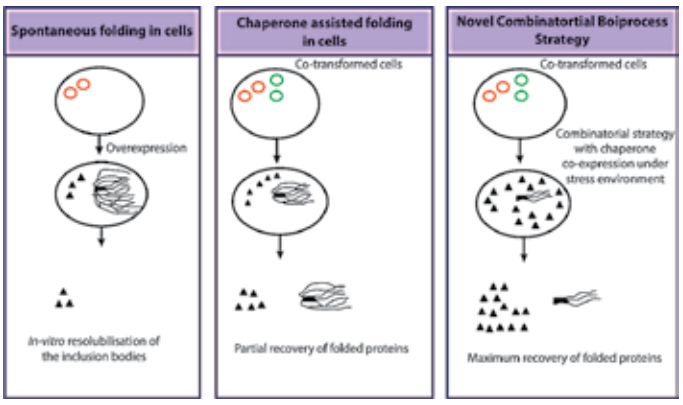


**Figure 2:** Representation of various processes to enhance the functional recombinant protein production in the E. coli cells. The conventional method of protein preparation by the spontaneous folding of protein in the E. coli cell system yields protein in the inactive aggregates known as inclusion bodies. The coexpression of molecular chaperones in the co-transformed cells can only partially recover some of the misfolded proteins. The E. coli cells subjected to novel combinatorial strategy yielded maximum recover of the functional recombinant protein.

The main objective of the present invention is to provide a process for expression of biologically active recombinant proteins in Escherichia coli cells. Here we have proposed a combinatorial bioprocess strategy to enhance the functional protein production in the cells. Several bioprocess strategies including co-expression of molecular chaperones, reduced incubation temperature during cell growth & expression and physiological cellular stress conditions including heat shock and osmotic shock are known to affect the solubility of the recombinant protein expression in the cells. A novel combination of these strategies developed for the E. coli system has shown an incredible increase in the functional recombinant protein production compared to the individual process effects. This unique process utilises the folding assistance modulated by the molecular chaperones expressed both by the in-house and exogenous systems. The novel process has immense applications in the functional recombinant protein production of aggregation-prone proteins in the cells.

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